TECH ENGINEERING NEWS

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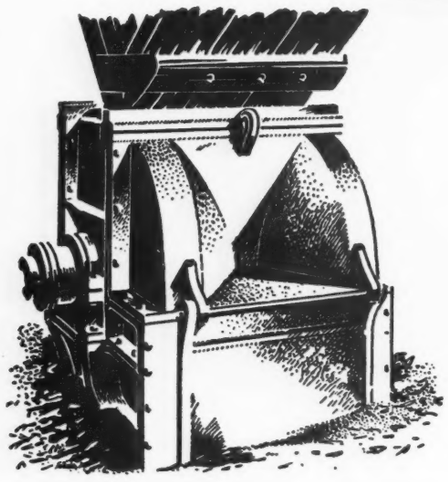

How to improve a wood hog's appetite

The wood hog shown here chews up logs for paper pulp like a giant pencil sharpener. As they chip away at the logs, the revolving cutter knives impose heavy shock loads on the bearings. To carry these shock loads, engineers specified that the cutter shaft be mounted on Timken® tapered roller bearings. Due to the line contact between the rolls and races, Timken bearings have extra load carrying capacity —take the heaviest shock loads.

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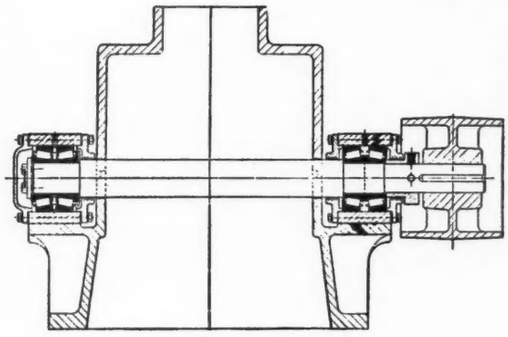

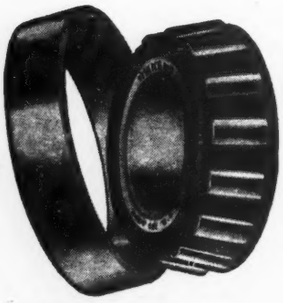

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Why plant engineers never omit the "Composite Valve" — in any cost-wise planning

CALL IT THE "COMPOSITE VALVE" — the giant that would result if *all* the valves in a plant were *one* valve. As pictured here, its proportion to other equipment in this detailed model of an automobile factory is fairly accurate. Representing the total valve investment, its size may surprise you, but it must be considered in any plan for economical plant operation.

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"PRACTICAL PIPING LAYOUTS" is a 32-page book containing diagrams and descriptions of 25 basic piping layouts with complete recommendations for valve selection and location in the lines. Tells you "which valve where for best performance". FREE on request. Write JENKINS BROS., 80 White Street, New York 13, N. Y.

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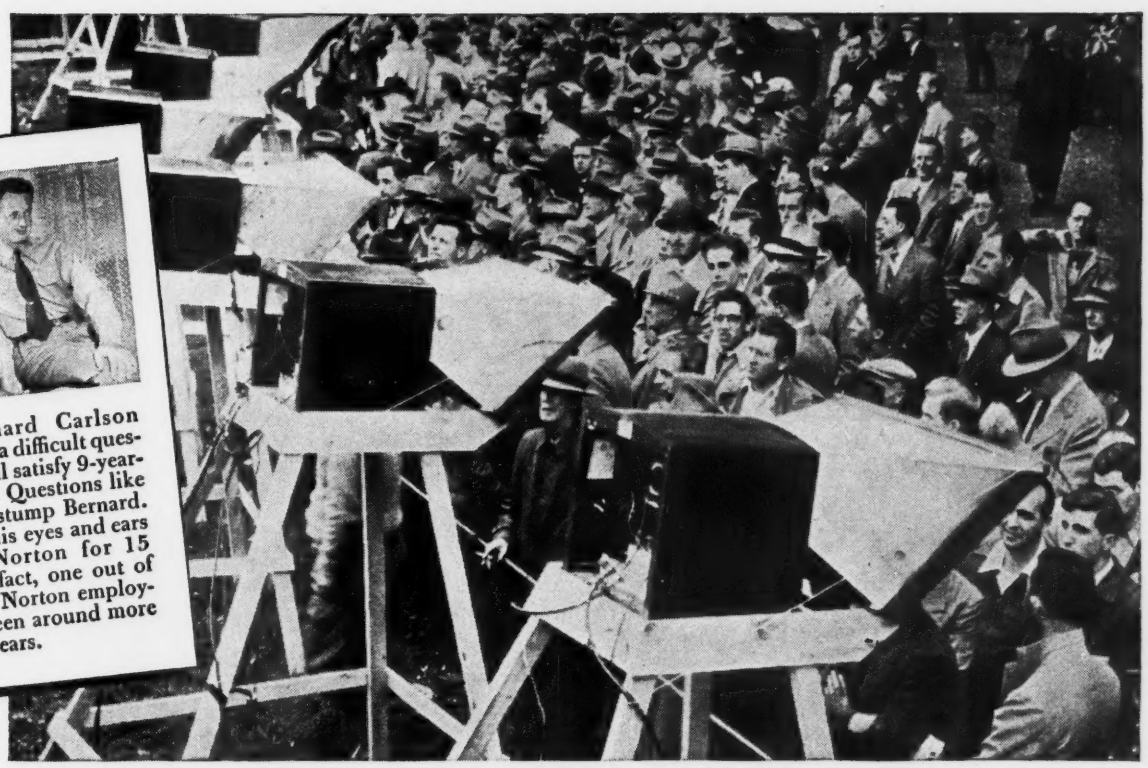
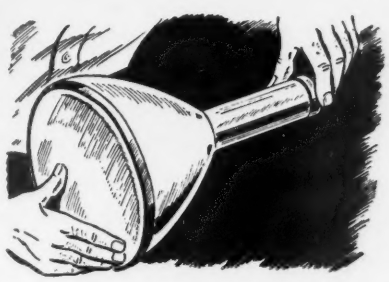


How Bernard Carlson might duck a difficult question and still satisfy 9-year-old Jackie. Questions like this don't stump Bernard. He's had his eyes and ears open at Norton for 15 years. In fact, one out of every two Norton employees has been around more than 10 years.

News photo of crowds watching television on Boston Common.

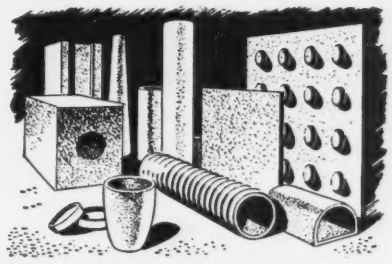
BUT, DAD, WHAT MAKES TELEVISION SO CLEAR?

"Lots of things, Jackie! But mostly brains. The brains of men who know how to make electrons behave in tubes. Electrons are tiny particles of electricity. They're boiled out of metal wires by heating units. Much the same way as an electric stove boils water. But if the heating unit isn't right, everything goes wrong."



"The tube people are smart, son. They make sure the heating units give off the right heat and last longer by coating them with a fine Norton refractory. Alundum 38900 grain, we call it. It's so fine that ten grains end to end equal the thickness of a piece of paper.

'Alundum refractory grain is great stuff. Its melting point is 2015°C. That's real hot! Made into corrugated baffle plates, it doubles the efficiency of enameling ovens. That's why the surfaces of such things as refrigerators and electric stoves come so hard and smooth.



"Some people know Norton only as the world's largest maker of grinding wheels and machines, Jackie. But refractories in many sizes, shapes and materials are important Norton products, too. They're used in kilns, furnaces and ovens whenever industry wants to get the most out of high temperatures . . . safely."

"So, you see, son, from television tubes to refrigerators, Norton Products help make all kinds of products better. That's why the experienced heads and willing hands that make up the Norton team try a little harder to make Norton products better."

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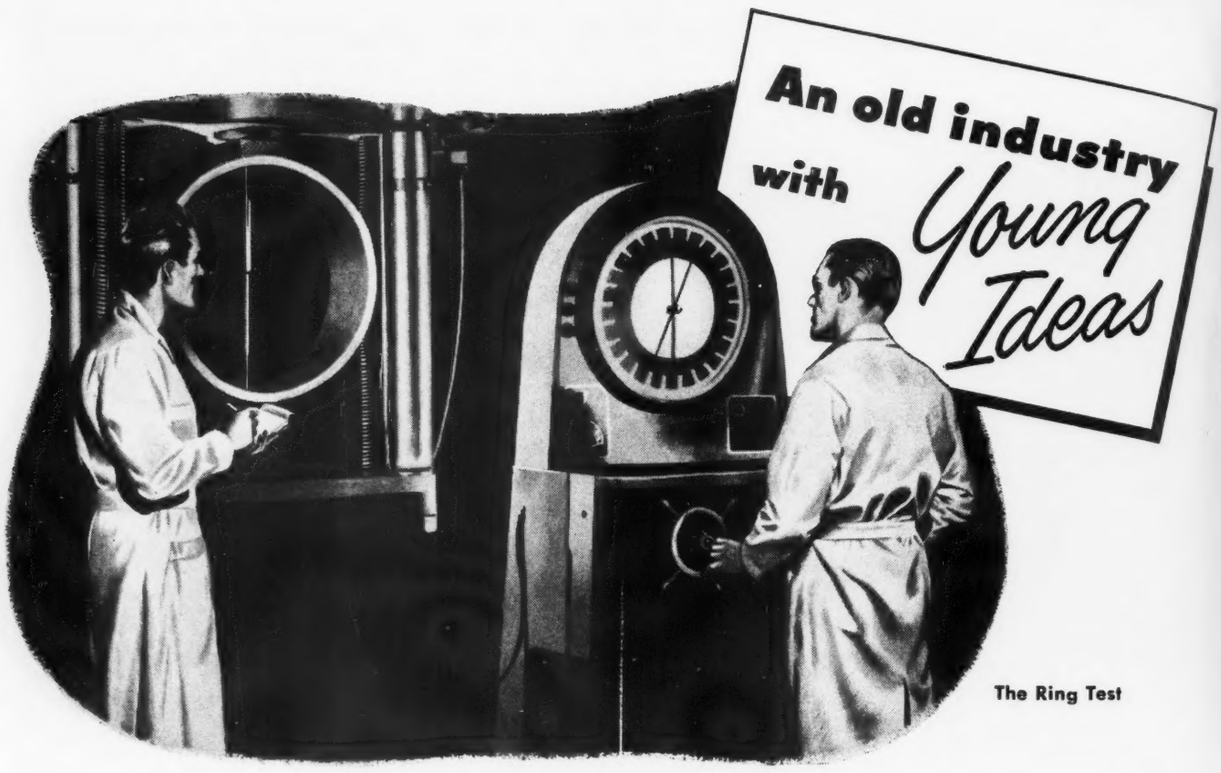

The Ring Test

The ring test, shown above, is a scientific method for determining the modulus of rupture of pipe. It is not a required acceptance test but one of the additional tests made by cast iron pipe manufacturers to ensure that the quality of the pipe meets or exceeds standard specifications.

A ring, cut from random pipe, is subjected to progressively increased crushing load until failure occurs. Standard 6-inch cast iron pipe, for example, withstands a crushing weight of more than 14,000 lbs. *per foot*. Such pipe meets severe service requirements with an ample margin of safety.

Scientific progress in the laboratories of our members has resulted in higher attainable standards of quality in the production processes. By metallurgical controls and tests of materials, cast iron pipe is produced today with precise knowledge of the physical characteristics of the iron before it is poured into the mold. Constant control of cupola operation is maintained by metal analysis. Rigid tests of the finished product, both acceptance tests and routine tests, complete the quality control cycle. But with all the remarkable improvements in cast iron pipe production, we do not forget the achievements of the early pipe founders as evidenced by the photograph below of cast iron pipe installed in 1664 to supply the town and fountains of Versailles, France and still in service. Cast iron pipe is the standard material for water and gas mains and is widely used in sewage works construction. Send for booklet, "Facts About Cast Iron Pipe." Address Dept. C., Cast Iron Pipe Research Association, T. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3, Illinois.

Section of 285-year-old cast iron water main still serving the town and fountains of Versailles, France.

CAST IRON PIPE SERVES FOR CENTURIES

THE CASE OF THE

Expanding Spandrel

Night and day, winter and summer, year after year, for more than twenty-six years aluminum spandrels (the vertical area between windows in skyscrapers) were exposed to the weather . . . and nothing happened.

That was proof enough for the architects.

Proof that Alcoa Aluminum castings used for spandrels stood up in all kinds of weather, resisted corrosion, kept up their good appearance, never needed maintenance.

"Aluminum works so well for spandrels," reasoned the architects, "why not expand its use . . . make entire walls of it?" They came to Alcoa with their ideas. Alcoa engineers had kept pace. Designs and methods for making complete walls were ready. New ways had been found to make aluminum cheaper and more useful.

Today you will see aluminum-clad buildings going up in every part of the country. These buildings are quick and inexpensive to build. Their aluminum walls never will need expensive painting or repairs.

This case is typical of the history of Alcoa and of the men and women who work for it. While aluminum was proving itself in small applications, Alcoa engineers were perfecting the methods for large scale production and fabrication. Within the lifetime of men now living, this company has grown to be one of America's great industries. New developments now underway in Alcoa's laboratories are pointing the way to even more widespread uses for aluminum in the years ahead. ALUMINUM COMPANY OF AMERICA, Gulf Bldg., Pittsburgh 19, Pennsylvania.

ALCOA FIRST IN **ALUMINUM**

tech engineering news

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meet the gyrocompass

By Louis Galan, '51

Of all the instruments ever devised by man to guide him in this world, the compass has been one of the most vital. So vital, in fact, that without it the golden age of world exploration would never have had such an early start, and it is reasonable to believe that our present civilization would be several centuries behind had it not been invented when it was. In spite of its long history, however, the compass has seen very few improvements since the Egyptians first used a piece of loadstone to get oriented. It was not until the early years of our present century that man looked hopefully to more precise and dependable means of orientation than the intricate magnetic field of the earth. Today we see in wide use the gyrocompass, whose accuracy and dependability are in accordance with the demands of our times. The principles behind this compass are simple mechanical laws, but the ingenious engineering tactics used to correlate these laws in order to achieve a true north-seeking instrument are very worthy of analysis.

As we must first know the alphabet before we learn how to read, knowing the gyroscope is an essential prerequisite to the understanding of the north-seeking gyrocompass. With that in mind we will first define and give a brief explanation of gyroscopic inertia and precession, then we shall continue with the principles of the gyro compass.

Gyroscopic inertia is that property of a gyroscope which keeps it at rest or in uniform motion unless acted upon by an external force. By mounting the principal axis of a gyroscope on gimbal rings such that all three mutually perpendicular axes intersect at one point and that this point be the center of gravity of the gyroscope and the gimbal rings, no external torques can be transmitted to the rotor and theoretically it will retain its original position relative to fixed space. This explains one of the peculiar behaviors of the gyroscope. If a gyroscope is left standing on the earth's surface its principal axis appears to rotate while actually it is the earth that rotates from under it. If left standing at the equator the principal axis appears to rotate about the horizontal axis. If placed at one of the poles it appears to rotate about the vertical axis. At all points between the poles and the equator the principal axis appears to rotate partially about the horizontal and partially about the vertical axis.

Precession is the most curious property of the gyroscope. It can be defined as a rotation which is perpendicular to the applied torque. To explain it let us consider four equal particles rotating on two perpendicular axes GE and FH at a velocity w about axis AB as shown in figure 1. Also assume AB to be mounted on gimbal rings and free to rotate in any direction. By exerting a couple on axis AB, forces are transmitted to the rotating masses by their radii. The distribution of these forces is such that in the shaded area of the figure they are directed upward with a magnitude ranging from a maximum at G to zero at H and E. In the light area the forces are of the same order of magnitude as in the shaded area but directed downward. Particle (1) on axis y has two components of velocity: a tangential component V by virtue of its angular motion and a velocity V_f resulting from the downward acceleration produced by the impressed downward force. There is an instantaneous resultant V_E directed somewhat downward. As the system rotates, particle (1) is accelerated down by the component of the impressed force until it reaches point F' below the x axis and enters the shaded area where the forces are oppositely directed. From F' to G the process is reversed and particle (1) has a somewhat upward velocity and it reaches point G on the axis y. From G to H the particle will continue to be accelerated upward and it will reach point H' above the x axis before it enters the light area where the forces are again downward. It proceeds in like manner from H' to E which lies on axis y. It is observed that while particle (1) is being accelerated upward particle (3) is accelerated downward and similarly for particles (2) and (4). The integrated effect gives us precession, which in this case is the rotation of the x axis about the y axis.

How were these two gyroscopic phenomena combined to produce a north-seeking compass? Let us assume that we are at the equator and that our gyroscope rotates about a principal axis AB in such way that the angular momentum vector points in the direction of B. By attaching a pendulum to the principal axis in such manner that it exerts no torque on it while horizontal, and place A pointing in the direction of east, we can observe a very interesting behavior. Due to gyroscopic inertia and the rotation of the earth, the axis will appear to tilt about the horizontal axis but no longer unmolested because as axis AB tilts it carries the pendulum with it and a torque is exerted on it about the horizontal axis. According to the precession behavior axis AB will rotate about the vertical axis and point A will move toward the north pole very slowly. As the earth continues to rotate axis AB continues to tilt and a torque continues to exist. The effect on the motion of point A is illustrated by figure 2 and its path is seen to

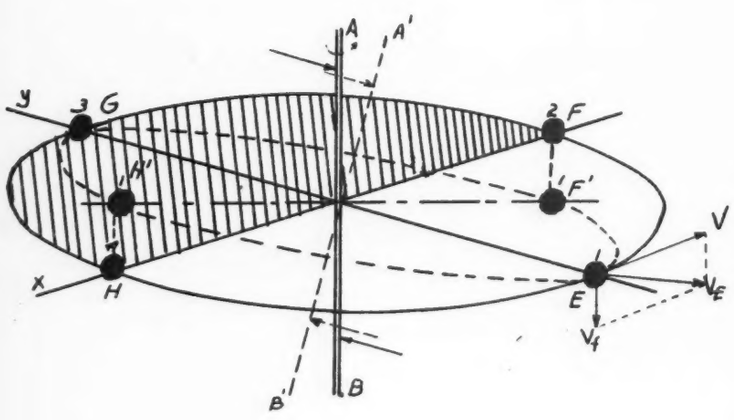
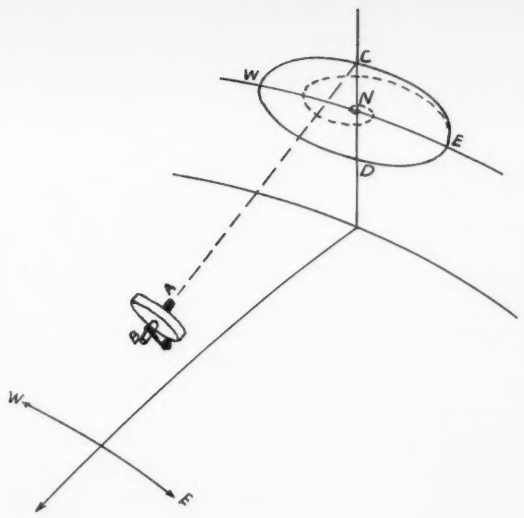


Figure 1. A couple about the x axis results in precession about the y axis.



follow an ellipse. As A reaches the position C the principal axis is parallel to the meridian, but it is still tilted so that the pendulum torque still causes the gyroscope to precess. As soon as A goes by the position C point B begins to rise due to the apparent axis rotation, and consequently A begins a downward tilt. Point B continues to rise and the axis continues to precess until A reaches position W and AB is again horizontal. While axis AB is horizontal the pendulum torque no longer exists and precession ceases. The earth, however, continues to rotate and point B of the principal axis continues to rise, tilting the pendulum once more which in turn causes a torque on AB. The torque is now in such way that the precession is in the opposite direction, and point A is observed to go downward and toward the east. The process continues until point A again reaches its starting position and proceeds for another cycle. The period of such oscillations is about eighty-four minutes.

It is evident that the device discussed thus far is inadequate to use as a compass because, among other things, to obtain a north reading one would have to plot the oscillations and calculate the center of the ellipse every eighty-four minutes. It follows that the next step in the development of a useful compass was to damp the oscillations of precession and tilt. This was a big step and without a doubt it was also the ingenious key to the successful gyrocompass.

The way the damping and self-correcting were perfected in the Sperry Gyrocompass seems to be an ideal method. As a pendulum the Sperry compass has a mercury ballistic which, in essence, consists of two tubes filled with mercury and lined up parallel with the principal axis. As the principal axis tilts mercury flows from the upper to the lower end of the tube and causes an unbalance equivalent to a displaced pendulum. The forces produced by this unbalance are not applied directly to the principal axis, but instead are placed eccentrically as illustrated in figure 3 so as to cause a torque about both the vertical and the horizontal axes. The torque about the horizontal axis we already know causes point A on the principal axis to precess toward the meridian. The torque about the vertical axis, however, causes precession about the horizontal axis, and this component of the motion coincides with the natural tilt due to apparent rotation. By aligning the eccentric torque properly this new precession can be made to oppose the natural tilt, thus introducing a damping effect. This damping effect can best be visualized by following the motion of point A as we did before, and the path is illustrated by the dotted line in figure 2. In commercial compasses the eccentricity is

Figure 2. Undamped and damped oscillations of the principal axis *AB* are shown in this drawing.

such as to make the damping factor sixty-six per cent. Once the principal axis comes to rest it will point directly north (if we remain at the equator) and the eccentrically placed ballistic will serve to correct any deviations that might occur, thus making the instrument self-correcting.

It appears as if we now had a true north-seeking gyrocompass, but the instrument thus far described will function only at the equator, since nothing was done with the component of apparent rotation about the vertical axis which exists at all other latitudes. Furthermore, before we can have a worthy compass we must have an instrument which reads accurately on a ship moving along the earth's surface at a considerable speed and unaffected by the rolling and pitching in rough seas.

At points other than the equator there is a horizontal as well as a vertical component of apparent rotation. This component causes our compass to deviate from the meridian. As soon as it deviates from the meridian, however, the natural tilt counteracts the deviation by causing the principal axis to precess toward the meridian. If it were not for the eccentricity of the applied ballistic torque the principal axis would eventually come to rest parallel to the meridian with one end tilted far enough so that the unbalanced mercury would cause a precession about the vertical axis exactly equal to the horizontal component of the apparent rotation. As long as the principal axis is tilted, however, there is an additional torque about the vertical axis due to the eccentric load. This causes the principal axis to tilt down so as to oppose the natural tilt. The result is that in northern latitudes the principal axis would come to equilibrium a few degrees east of the meridian at a point where the natural and eccentric components of tilt balance each other. This error is zero at the equator and increases to 2.9 degrees at 60 degrees latitude. No further attempt was made to have the gyrocompass correct itself for this error primarily because it is simple enough to introduce a latitude adjustment to the lubber ring of the indicator.

The gyrocompass was designed so that the principal axis lines itself up perpendicular to the direction of motion of its base. When the compass rests on the earth's surface, it lines itself up with the meridian because the meridian is perpendicular to the earth's rotation. What happens when the compass rests on a ship which moves, let us say, south relative to the earth at an appreciable speed? The base of the gyrocompass in this case moves in the direction of the vector representing absolute motion, which is the vector sum of the ship's velocity and the earth's rotation. The compass will point in the direction of an apparent meridian which is perpendicular to the absolute motion. If the ship moves in any direction other than north, the north or south components of its motions are the ones that shift this apparent meridian. A new correction must be introduced to the lubber ring of the indicator if we wish to determine true north. This is a curious correction because in order to make it we must know the ship's course, and to know the ship's course we need the compass reading. The correction is so small, however, that an approximate reading of the course is sufficient to determine the error. The correction mechanism used in the Sperry Gyrocompass is almost as ingenious as the compass itself.

(*Continued on page 26*)

a case for the streetcar

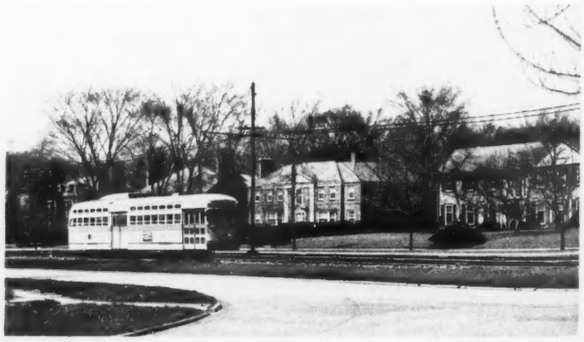
By David Klepper, '53

"Buses will replace streetcars on Massachusetts Avenue." Nothing is unusual about this announcement; it is simply a continuation of a pattern which has already ended street railway operation in scores of cities. First disappeared the small town lines, and out of the hundreds of such systems of ten years ago, only those of Fort Collins, Colorado, and Johnstown, Pennsylvania, can look forward to a bright future. More recently, the hatchet has fallen on the streetcar lines in our largest city, New York. Will this trend continue until the last streetcar rail is torn up and the last trolley returns to the carhouse?

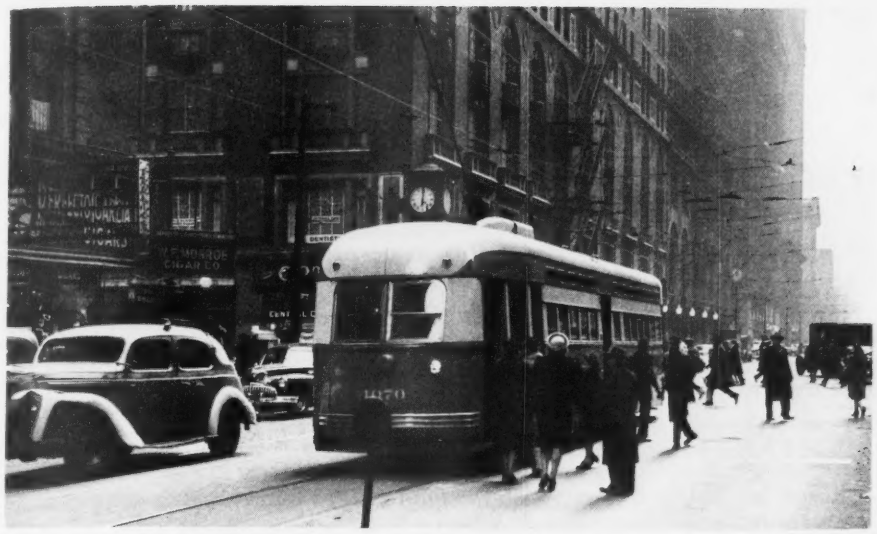
To many people interested in mass transportation the streetcar just does not appear that obsolete. They believe that the modern streetcar can solve many of our transportation problems most efficiently and with the least cost. Twenty years ago such men organized the Electric Railway Presidents' Conference Committee, known best by its initials, P. C. C. The basic objective of this committee was that of designing a car which would be attractive, so attractive that it could win the automobile owner from his private car to the public vehicle. Although other important and related considerations were extremely high, smooth acceleration and deceleration to permit the streetcar to lead, not impede, the traffic parade came first. Numerous experimental cars were built for the "P. C. C." and scientifically checked, in order that the final car would be a better performer than anyone ever dreamed a streetcar could possibly be. It was not until 1934 that this labor first bore fruit. In that year the Capital Transit Company of Washington, D. C. bought the first nonexperimental, fully streamlined streetcars. Although the P. C. C.'s research had not been completed by then, the Capital Transit Company had a great need for modern streetcars and decided to purchase new cars, using to advantage the progress made up to that time. These cars lacked the rubber sandwich wheels and automatic acceleration that distinguished the finished products, the P. C. C. cars themselves. Nevertheless, they proved that modern streetcars were practical, efficient, and patronage winning. Thus, when the P. C. C. car became a reality, there was a ready market for them, in Brooklyn, Washington, Pittsburgh, and Philadelphia, as well as other cities. Repeat orders for these cars were the rule. For the Boston Elevated, which wished to use these cars in trolley subway service, they were equipped with multiple unit control, to permit them to run in trains. In Philadelphia they ran on 5 foot 2 inch track, in Los Angeles on 3 foot 6 inch track. They were accepted in sunny California and in Toronto, Canada. They became the last hope of the street railway industry.

The construction and electrical equipment of the P. C. C. car have very little relation to that of older streetcars or of that of any vehicle. Very unique are the wheels of the car. A large factor in the general obsolescence of the streetcar was its noise. Thus, P. C. C. wheels were especially designed to remove the largest possible fraction of this noise. Rubber tires would be the best for this purpose, but the wearing qualities of rubber cannot compare with those of steel. The end result was a wheel having a steel tire separated from a steel hub by rubber in shear, not in compression. This combination has excellent wearing qualities, yet is sound insulated, and gives the smoothest possible ride. Adding to the quietness and smoothness of the car are the rubber springs of the truck frames and bolsters which transfer the weight of the car to the axles.

Another disadvantage of the old streetcar was its inability to start and stop quickly. The old hand-operated drum controller, with its low number of contact points, was both jerky and inefficient, and the deceleration caused by air brakes was limited by wet weather when the wheels would slide upon the rails. In the modern P. C. C. car an automatic accelerator with seventy points, operated by a pilot motor, insures high, 4.75 miles per hour per second, and constant acceleration. In braking, the motors are used as generators, thus the force required to turn the axles slows the car down. The energy generated by the motors is used in



Home owners along the Shaker Heights Rapid Transit leave their cars at home and take the electrics to Cleveland. *General Electric photos*



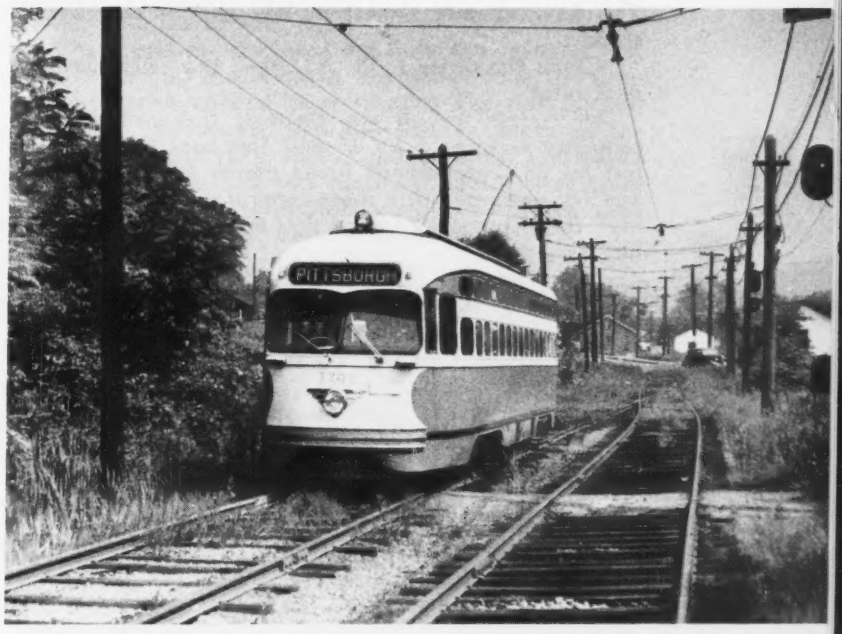
The wide doors of this Chicago car make for efficient loading.
General Electric photo

Pittsburgh Railways operates over 600 P. C. C. cars. No. 1707 helps shorten a 40-mile route's schedule.

the heating resistors. When the speed of the car has been brought down to less than two miles per hour, a solenoid-released, spring-applied brake is applied to the motor shaft, holding the car at a standstill. During wet weather and under emergencies a third brake is used. This is the magnetic brake which can be seen on the outside of the truck frame between wheels. This brake actually grips the track and holds it by the magnetism of its field coil. The combination of high acceleration and high deceleration results in very high schedule speed, since time required for stops is short and cars can safely be operated at high speeds.

High schedule speed, smoothness, and lack of noise will not alone win patronage. What is also needed is a comfortable car and an attractive one. The streamlined exterior of the car makes it attractive on the outside; soft leather upholstered seats and proper ventilation provide a comfortable interior. A longitudinal duct may be seen on the roof of recently built or remodeled P. C. C. cars. This duct has louvered side walls and is divided by cross partitions into three outlet sections and three air intake sections. Three motor driven ceiling fans draw air from the intake sections and discharge into the car through diffusion grilles. The speed of the fans is regulated by thermostats, as are the heating dampers. In the very latest P. C. C. cars this ventilating system is combined with special heat resisting window glass to make the interior of the car very cool in hot weather. In cold weather, the heating resistors have an unlimited supply of electrical energy to draw on. Never too hot or cool, a P. C. C. car's interior is always at the proper temperature for a transit vehicle. Other factors in the comfort of the cars are their roominess, the one feature that always distinguished the interior of an electric car from that of a bus. The wide aisle, the stainless steel poles, and the extremely smooth motion of the car take most of discomfort out of the inevitable rush hour standee's ride.

One might expect that a car so well designed should find no difficulty in being accepted everywhere. Unfortunately, this is not the case. In many cities the only streetcars that people knew of were the familiar old, noisy, and uncomfortable ones, and any comparisons between streetcars and buses were always drawn between these obsolete cars and modern buses. People thus thought that all streetcars must be uncomfortable. This thinking even invaded the minds of transit executives themselves. An outstanding example of this is the recent history of electric cars in New York. In 1935 the Third Avenue Transit Company was embarking on a program of modernization which was to include the



purchase of modern buses for new routes and for lightly traveled streetcar routes, and new streetcars for the heavily traveled lines. The buses that were bought were the most modern of their day and had comfortable leather seats. The streetcars, which were to operate on the main surface line of New York, the Broadway and 42d Street line, did not utilize one of the important advancements of streetcar design brought about by the P. C. C. — the seats were standard straw straightbacks taken from scrapped antiques. Even though they had great capacity, something very necessary but quite lacking on Manhattan's surface lines, they were recently replaced by buses which gave the riders some degree of comfort and speed. These riders never had a chance to see what a truly modern streetcar was; consequently, many of them preferred the bus.

The reasons for the comfort of the modern streetcar have been pointed out already, and there is no need to review them. It must be mentioned, however, that this comfort compares very favorably to that of the bus, especially as regards the smooth travel afforded by the steel rail against the unevenness of that of a road. Where P. C. C. cars were put into service passengers liked them. However, not only from the passenger's viewpoint but from an intelligent transit manager's viewpoint, P. C. C.'s are a good investment. A survey

(*Continued on page 28*)

finite differences

By Thomas Erber, '51

The reader is actually already familiar with the general subject of "differences"; the entire field of mathematics under which we group the differential and integral calculus is nothing but the study of infinitesimal differences. It is the purpose of this article to give a brief introduction into the complementary field of finite differences.

The most elementary problems of the regular calculus grow out of the determination of the slope of a curve at any given point. The finite difference calculus may be approached through analogous methods. You have all met something like this on intelligence tests:

Given the series 1 8 27 64 125 216; find the next term.

Of course we all see through the problem; the sequence is formed by x^3 and the next term is 343, but let us forget about being clever for the moment and try to figure out a more general method of "cracking" the sequence. A good first try will run something like this: take the differences of the successive terms and see how they run. By gauging the increase from difference to difference and applying a little mental "body english" to the numbers, a good stab can be made at the next term. Improved methods will involve taking more and more differences until the last difference remains fairly constant and so helps to evaluate the next term. A diagram would look like this:

(1)

$x =$	1	2	3	4	5	6	/7
$y(x) = x^3$	1	8	27	64	125	216	/ 343
$\Delta^1 x^3$	7	19	37	61	91	/ 127	
$\Delta^2 x^3$	12	18	24	30	/ 36		
$\Delta^3 x^3$	6	6	6	/ 6			

This is indeed a pleasant surprise, the third difference seems to be constant. If we assume *all* the terms in the third difference to be 6, we can, by adding differences, get the next term in the sequence. It is useful to note in passing that we needed *three* differences to get a constant term for a *third* degree polynomial; the constant term is 6, equal to $3 \times 2 \times 1$ or a "three times" differentiation of x^3. A more powerful mathematical generalization of our simple example can be made as follows: Rewrite the sequence and its various differences in terms of y_x, where y_x stands for the value of the x^{th} term in the function $y(x)$. For example: $y = 6x^2$; $y = 24$. The superscript n on Δ^n signifies that it is the n^{th} difference. So we have:

(2)

$$\begin{array}{cccccc} y_x & y_{x+1} & y_{x+2} & y_{x+3} & \cdots & y_{x+n} \\ \Delta^1 y_x & \Delta^1 y_{x+1} & \cdots & \cdots & \Delta^1 y_{x+n-1} & \\ \vdots & \vdots & & \vdots & & \\ \Delta^n y_x & \Delta^n y_{x+1} & \cdots & \cdots & \Delta^n y_{x+n-1} & \end{array}$$

(3) We see then that: $\Delta^1 y_x = y_{x+1} - y_x$

(4) or: $y_{x+1} = y_x + \Delta^1 y_x$

(5) then: $y_{x+2} = y_{x+1} + \Delta^1 y_{x+1}$

(6) substituting for y_{x+1}:

$$y_{x+2} = y_x + \Delta^1 y_x + \Delta^1 (y_x + \Delta^1 y_x)$$

To evaluate this last expression it will be necessary to make a slight detour:

(7) $$\begin{aligned} \Delta^1(u_x + v_x) &= (u_{x+1} + v_{x+1}) - (u_x + v_x) \\ &= u_{x+1} - u_x + v_{x+1} - v_x \\ &= \Delta^1 u_x + \Delta^1 v_x \end{aligned}$$

The Δ obeys the distributive law and we can write:

(8) $$y_{x+2} = y_x + \Delta y_x + \Delta y_x + \Delta\Delta y_x$$

Before the result can be written in its neatest form, we must understand $\Delta\Delta y_x$. This is rather simple: from the meaning of $\Delta y_x = y_{x+1} - y_x$ we get:

(9) $$\Delta\Delta y_x = \Delta y_{x+1} - \Delta y_x$$

or:

(10) $$\Delta\Delta y_x = y_{x+2} - 2y_{x+1} + y_x$$

This means that it makes sense to apply the Δ twice to the same thing. We are fortunate in this. There are some functions where it is impossible to apply the function twice. As an example take F defined as follows: $F(x,y) = Z$. The F is a "machine" which takes two variables, x and y, mixes them up in some way, and delivers one variable. $F[F(x,y)] = F(z)$ doesn't make sense because we have so constructed our F, the machine, that it works on two variables *only*. When we feed it one variable, the answer is undefined. But with the Δ machine, the one that takes a function of x and makes "function of $x + 1$ minus function of x" out of it, we clearly don't run into that trouble. Now we can go ahead and sensibly define $\Delta\Delta y_x = \Delta^2 y_x$ for the sake of convenience. The original expression (5) can then be written:

(11) $$y_{x+2} = y_x + 2\Delta y_x + \Delta^2 y_x$$

and y_{x+3} can be written:

(12) $$y_{x+3} = y_x + 3\Delta y_x + 3\Delta^2 y_x + \Delta^3 y_x$$

We now recognize the coefficients on the right hand side in the two equations above, 1 2 1 and 1 3 3 1, as being the coefficients of the binomial expansion of $(a + b)^2$ and $(a + b)^3$. Jumping to the conclusion, we write:

(13) $$y_{x+n} = y_x + n\Delta y_x + \frac{n(n-1)}{2 \cdot 1} \Delta^2 y_x + \ldots$$

A very powerful and neat proof of the foregoing can be obtained by operational methods. By now, most of the readers will have noticed that Δ is actually an operator; these operators are the elite of the function kingdom in that they never deign to work on the variable, say x, itself, but only on the functions of x. This seemingly offensive snootiness has its uses as we shall shortly see. Suppose that we now use this newfound definition, "operator," and define a very simple one — E. We agree from now on that $E(y_x) = y_{x+1}$. It follows immediately:

(14) $$EEy_x = Ey_{x+1} = y_{x+2} = E^2 y_x$$

and in general:

(15) $$E^n = y_{x+n}$$

But:

(16) $$\Delta y_x = y_{x+1} - y_x \text{ or } y_{x+1} = \Delta y_x + y_x$$

Symbolically speaking, we can "factor" y_x out of this and obtain:

(*Continued on page 32*)

day, the eighth

By Rudolph Preisendorfer, '52

"*. . . And the earth and her heavens shall take a new start amongst My habitable worlds.*"
Oahspe, *Synopsis of Sixteen Cycles. Chapter III, 30.*

No searing, tearing, thundering atomic blasts of warring Earthmen.
No malevolent, terrifying, crawling beetle horde.
No returning ice age.
No Nova.
Just . . .

A mild, rippling clap of thunder, and the teeming thousands that had occupied the metropolis were no more.

At the antipode of the Earth where another teeming city lay in sleeping repose, the rippling clap of thunder was muffled; its component reports issued mostly from within the walls of the soaring towers, where dwellers lay in unsuspecting slumber. The resounding sharp staccato cracks of sound here and there on the deserted streets were few in number, and told the listening walls of the annihilation of some nocturnal prowlers.

On the other side of the Earth, in still another huge metropolis, a huge, sun-bathed bowl was filled with cheering thousands, who had gathered to witness a favorite sport attraction. At the instant of doom, the echoes of the sounds from the throats of the multitude mingled briefly with the sharp report of imploding air. A tiny flurry of peanut shells and popcorn boxes and dust settled in the wake of the slightly disturbed atmosphere; settled into an empty grandstand.

A milli-light second away, a sleek, silver trans-continental jet transport was preparing to land on the runway of the seacoast jet-port. Its whistling jets were just above idling, and the craft was angling into a shallow glide. Inside, the pilot had switched to automatic, and the ground-air control was guiding the machine to the ground. The pilot turned to his . . .

The report was sharp, short and mild. The descending craft was pilotless. It whistled and breathed out a vapor trail as it glided closer to the earth. The landing tracks extended themselves below the swept-back, clipped wings . . . the machine hovered over the strip . . . the tracks touched . . . perfect landing. The ship braked itself, and came to a smooth halt. It shut its jets off, and then perched silent and immobile on the sun-bathed runway.

The whirring of many wings in the crisp, clear autumn morning air told the farmer that the birds were flying south again. He glanced upward at the morning blue, and beheld that it was dense with innumerable sets of ragged, trailing vees. The sun was just rising and the farmer was preparing to start another day. He ambled slowly toward his big red barn which was redder still in the early morning glow, to turn out his livestock. He pulled back the huge, weather-beaten door, took one last glance at this beautiful autumn sky . . . .

When the tiny shreds of hay and flakes of manure settled, there was no more farmer, no more livestock, and the autumn morning sky was just as blue and clear and empty as could be.

So it went around the world. The annihilation swept across the surface with the speed of light. The only indications of this total destruction of fauna were the impotent sounds of the atmosphere rushing into the vacuum left by the departed bits of flesh, and a local flurry of resettling matter that was carried along by the inrushing air, and that was all.

The works of Man went next.

The towering, silent, empty metropolis stood in all its majesty at the bank of the wide, blue river which emptied into the ocean a mile or so away. Its tall, graceful towers were bathed in brilliant white from the noonday sun. Its deserted streets resounded with no sounds of bustling life. All was silent. Here and there, the picture of absolute immobility was disturbed by the random weavings of light rubbish and yesterday's newspapers which were carried along the empty boulevards by the fresh sea-breeze.

The sound reverberated for fully five minutes. It started way up in the scale, but before long the deep rumbling roar reached its crescendo. The dust kicked up was a little more than the manure flurry in the farmer's barn, or the rustle of peanut shells and paper boxes in the stadium; as a matter of fact, it was quite impressive . . . but there was no one on Earth that could have been impressed at the moment.

The multitude of gaping holes left by the departed towers were rapidly being filled in from the muddy torrent sent by the disturbed river, or by the collapsing, unsupported earth walls of the holes themselves.

The airport, the deserted jet-job, the stadium, the barn, all were gone. Now the Earth floated in all her bare splendor, clothed in its forests, mantled by its meadows, bathed by its seas, and armored by its mountain ranges.

The works of Nature went next.

The grasslands of the Earth disappeared in a full-throated, long-drawn-out, rumbling ping.

The forests and woodlands disappeared with a symphonic accompaniment a full octave lower.

The seas gave valiant battle. They fumed and steamed, and gasped, and roared, and made the phonic demise of Man's greatest works sound like a muted whisper. Then, they too were gone, leaving parched, black sockets gaping darkly into the turbulent atmosphere.

What was left?

A rotating ball revolving about its glowing primary, which gazed down upon its nude daughter with utter unconcern.

That is not all.

The atmosphere went next.

It just went.

The bright, unwinking diamonds of the skies shone unseeing upon the dark brown ball of clay. Its skin began to crawl. In complete silence, the unsightly rashes that were the mountain ranges of the Earth disappeared, sinking into the yielding magma. The readjusting crust strained and complained in silence. The parched, black sockets grew less defined . . . filled. Slowly, but surely, depression met elevation, and merged. Isostatic equilibrium was reached, and the Earth assumed its geoid of minimum stress.

Now it revolved as a completely barren spheroid around the sun. Its flanks so smooth that the brilliant celestial points of light were almost mirrored on its convex surface.

(*Continued on page 36*)

m. i. t. a. a.

Tech's Largest Student Activity

By Robert Donovan, '52

Tech is not considered an athletic school. We do not subsidize our athletes; our teams practice fewer hours per week than any of our opponents; we are strictly amateurs. Even our athletic administration is composed, not of paid professionals, but of students who handle their positions as another extra-curricular activity. While other schools may also boast that their athletes receive no salaries, and that they too are totally amateur, no other can go quite so far as we and point to student officers of the athletic association. You may be interested in learning just who these Techmen are and how they handle their job, for they spend forty-one thousand dollars of your tuition money each year.

They have organized a body, the Massachusetts Institute of Technology Athletic Association — M.I.T. A. A. — with the object of "promoting and supervising athletic interests at M. I. T." The membership consists of the Association's officers, each team captain and manager, the manager of any recognized Institute sport, and the Director of Athletics, Mr. Ivan J. Geiger, who is the only non-student member of the Association. Each of these members has a vote on A. A. matters, while the non-voting block is composed of associate members and any interested parties.

The officers of the A. A. are the President, Vice-President in charge of Varsity Sports, Vice-President in charge of Intramural Sports, Treasurer, Equipment Manager, and Publicity Manager, who hold office for one year or until their successors are approved. Any past or present member of the Association who would, if elected, serve the major portion of his term of office while a member of the junior or senior class is eligible for election to the Presidency or Vice-Presidency. The Treasurer, Equipment Manager, and Publicity Manager are appointed by the retiring Executive Committee. These officers form the new Executive Committee of the Association; and it is up to them to keep the organization running smoothly. To do the job of one of these offices well demands a background acquired by working as an assistant in the department involved for at least a year.

The President's only duty is to preside at the meetings of the Association; but, by presiding, he can influence A. A. policy immensely. Although not a written requirement, the President must be able to keep spirit and cooperation high in the Association; he must lead the A. A. His work is not cut and dried but is largely up to himself to determine. The present President, George Lopez, feels that a good president should understand the aim of the Association, which is to have as many Techmen as possible participating in athletics.

The duties of the Vice-President in charge of Varsity Sports are much more sharply defined than those of the President. He must conduct the competition for managerial positions of varsity sports and advise the Executive Committee as to the qualifications of each competitor. He determines external eligibility, supervises the distribution of all class numerals and letters, keeping a file of these awards along with the athletic records of the Association. In the absence of the President, he presides at A. A. meetings. Richard Rorschach, a senior in Course XVI, is this term's Varsity Vice-President.

The Intramural Vice-President's job is quite similar to that of the Varsity Vice-President except that he supervises the intramural managerial competition and determines intramural elegibility. At A. A. and Exec-

The A. A. goes through the dull business of having its picture taken before embarking on a discussion of the business it has at hand.

Rockwell Cage was the scene of this Hexapoppin' skit during the Tech's-a-poppin' week-end sponsored by the Athletic Association.

The job of the M.I.T.A.A. ranges from the expected to engaging an orchestra for Tech's-a-poppin's dance.

utive Committee meetings he keeps the minutes, a copy of which he must forward "within forty-eight hours" to the Secretary of the Athletic Board (a committee of administrators and undergraduates). Amiel Brinkley, like Rorschach, an S. A. E. man, is Intramural Vice-President.

As custodian of all funds of the A. A., the Treasurer finds himself in quite a responsible position. Since all funds disbursed by the A. A. can be honored only on the Treasurer's signature, he must draw the line between good and bad investments. Refusing to grant money requested by a manager or a coach requires quite a bit of tact on his part or else he is quite likely to find himself with some bitter enemies. All managers submit a budget of estimated expenses for their sport, which the Treasurer either approves or rejects. Once a budget is approved, the limit is set, and only by special application to the Treasurer can a sport be considered for additional funds.

The forty-one thousand dollars the A. A. spends each year must be accounted for by the Treasurer. The experience gained from a year at this job is invaluable, as Randy Gibson, the Treasurer incumbent, will testify; but it also takes much valuable time, as Gibson will also testify. He spends from twenty to twenty-five hours per week in A. A. interests; but, being responsible for forty-one thousand dollars, he is not willing to take any shortcuts. Actually he is taking an additional course, a practical Course XV in the athletic office as well as electrical engineering at school.

About twelve thousand dollars per year of the Treasurer's funds are spent for new equipment. The actual purchasing is done by the Equipment Manager. This means scouring over the market and finding the best buy as well as the proper items. Again much responsibility is borne by the student officer, for every Tech team depends on him to have the proper equipment at the proper time at the proper place. Equipment Manager Ralph Thornton says he has little trouble in contacting sellers because they flock to see him with their bids for outfitting Tech teams. He takes great pride in the manner in which he whittles salesmen's original prices down by comparing with other prices and by shrewd bargaining. In addition to buying all A. A.

The managers of each sport arrange the schedule for each season with very little supervision.

equipment, the Equipment Manager must supervise the distribution of it and keep records of who has what. It is he whom you curse when you are billed for missing equipment.

Both the Treasurer and the Equipment Manager have several assistants who do the less skilled work while becoming familiar with A. A. procedure. While working as assistants they are classified as associate members of the Athletic Association and are urged to attend all meetings. It is they who will eventually matriculate into the officer's position.

At present the Director of Athletics, Mr. Geiger, is an adviser and a spreader of goodwill. His required job is only that of advising the A. A. on matters that he, from his experience and contacts, is much more able to help along. In addition to this he has been building up athletics ever since he came to Tech. By arranging athletic contests with other schools, he has increased intercollegiate competition to the point where varsity teams were playing more games per year than ever thought possible. His plans for the future are not definite but the upward trend is sure to continue. The construction of the new gymnasium means better facilities for varsity competition as well as intramural and individual participation and is typical of the bright outlook for Tech athletes of '51, '52, '53.

The manager of a Technology varsity team or sport finds that he has a job that demands more initiative and work than the same position would at another school, for he must arrange and draw up contracts with all schools he proposes to compete with, and submit a report to the Treasurer of the expenses of the contest — this above and beyond his original season budget which the Treasurer asks him for near the beginning of the season. These financial worries are in addition to the usual managerial tasks of keeping boxscore at games, and seeing everything is in order for practices and games. Obviously a good manager can do much to build up a good team and see that they have a successful season, while a poor one can do just the opposite. Thus in the Athletic Association Constitution there is an article stating that before a man can be appointed to a manager's office, he must have served at least six weeks as an assistant.

The Team Captain's main duty is to be personally responsible for morale and sportsmanship of his team. He is required to submit a written report of the activities of his sport to the Varsity Vice-President before each monthly meeting, for the sake of formality.

Serving as a legislative body for the Athletic Association is the Athletic Board, representing a cross-section of the parties interested in Institute Athletics — the undergraduates, the alumni, the faculty, the administrative, and the medical departments. It is the job of this group rather than any single person to determine athletic policy. They meet once a month usually at the home of a professor or an administrator, where the meetings sometimes last till the next morning. A tradition among the members of this group is that all decisions handed down by them must be reached by an unanimous vote.

Two years ago the Athletic Association struck upon the idea of a sports week-end, patterned after the Dartmouth winter carnival. This week-end was designed to emphasize sports and more specifically, sports at Tech. The idea behind this week-end was summed up succinctly by Paul McNaughton, '49, one of the inaugurators of the event, when he said that somewhere around Tech there must be the same spirit and enthusiasm that is so evident at the athletic contests of other schools. He has watched hordes of devoted spectators cheer madly the teams of Harvard, Yale, Penn and Princeton, whether they be good or bad, and at the same time seen our own teams fight just as hard with few other than their teammates to acclaim their efforts or to extend a hearty pat on the back. Lack of time and lack of interest of the student body has caused this situation. Tech's-a-poppin' week-end provides the time and certainly the interest to let that latent Tech spirit break loose and really unite the student body behind the team on the field. McNaughton recalls the first Tech's-a-poppin' hockey game in the Boston Arena. Tech was absorbing a good shellacking at the hands of B. U., but the first Technology score just about lifted the roof off the auditorium, as thousands of Techmen let loose lusty yells that had been mounting within them from the first B. U. tally. It was truly an inspiring scene.

stop and look

Technology as a Museum

By Raymond S. Ghosn, G. and Richard C. Reece, G.

A diversified series of exhibitions creates a changing scene in Building 7 Lobby. It is here that members of the Tech family have come in closest contact with exhibits. Although occasionally of a technological nature, these exhibits tend more often in an arts direction, an attempt aimed at extending the liberal education of the technological student.

President Killian observed in his Inaugural address the necessity for achieving "a better synthesis between professional education and general education," stressing the importance of "programs in the humanities and social sciences helpful in developing a sense of values pertinent to the society in which we live." Exhibitions at Tech are but one facet of a broad General Humanities Program, a definite factor contributing to the interest and variety of Institute life.

As exhibition space, Building 7 Lobby has presented problems to the exhibition designer. The high dome ceiling only tends to increase the apparent volume. Special treatments are necessary to establish a human scale — preventing the patron and the display itself from being overwhelmed by the emptiness of the tall space. The existing six-way circulation pattern in the Lobby discourages organization of an orderly sequence. Usual exhibition technique dictates a text sequence reading in clockwise direction — a logical consideration since it follows that the printed word is read from left to right. To "tell the story" successfully, order, unity and progression must be accounted for. Exhibition expression — a short cut to knowledge — is at best a graphic medium. Its informative task is to convey a clear impression by visual means.

At the same time, the selection of exhibits for Building 7 Lobby has also been hampered by security considerations. Circulation space, getting the wear and tear of Grand Central Station, is hardly the place for a priceless Rembrandt. The lack of complete security has prevented the display of precious collections and has imposed a limitation on the scope and consequent educational value. The Institute's need for protected exhibition space is met in the new Hayden Gallery. In one important respect, Building 7 Lobby has proved to be a remarkably effective showplace — having the advantage that almost everyone passing through the Institute must pass by the exhibition. While the Hayden Gallery is also served by a major thoroughfare, it enjoys the added advantage of being located by the *side* of a traffic stream rather than blocking the flow.

Here is a view of last year's acoustics exhibit which most viewers probably did not see.

For anyone interested in General Science, this "Junior Open House" showed interesting material from many departments.

Great pains are taken to produce exhibits in Building 7 as striking as this one.

An architectural preview of the new gallery suggests an exciting room of agreeable proportion. Large glass walls separate the gallery from garden-terrace and entry. Two solid walls covered with natural linen provide hanging space. Free standing exhibition frames of natural birch will supplement the wall space. An illumination system including a number of spotlights insures a range of dramatic lighting possibilities. A white ceiling and a white and dark green terrazzo floor will set the simple background suitable for valuable collections. An exhibition of recent Braque paintings, to speak of only one among the forthcoming monthly exhibits, will strike a pleasant note in this surrounding. Georges Braque (1881) collaborated with Picasso in the development of cubism — a particular type of painting initiated in Paris about 1910. According to Henry Russell Hitchcock in his book "Painting Toward Architecture," "the early Braques of the years of the first World War have played as great a part as the early Picassos in forming the tastes of the first modern architects. Late Braques are less upsetting than late Picassos in the intensity of their plastic research; but they are pictures for architects as well as for others to live with."

Despite the limitations of Building 7 Lobby, many stimulating exhibits have been staged there successfully. Each year one department at M. I. T. presents some phase of its activity in exhibit form. Such exhibits may ultimately be circulated to schools, colleges, and alumni clubs. A particularly skillful solution was the acoustics exhibit that appeared in December 1948. This year the Meteorology Department, in collaboration with the American Academy of Arts and Sciences, will present a show interpreting various meteorological phenomena.

Short term exhibits will continue to appear presenting as in the past the fine arts, painting, sculpture, photography, as well as related subjects, textiles, furniture. Spectacular past exhibits have not failed to make lasting impressions. The "Twentieth Century American Watercolors" included one of the largest number of John Marin's paintings that had ever been shown locally. As last year saw a collection of paintings from the Upper Mid-West, this year will bring a group of paintings representing the New England area. The "Henri Cartier Brisson" photographs reflected in their subject matter the international range of his camera. The Museum of Modern Art's show "Built in U. S. A.," presenting a survey of contemporary American architec-

ture, included some of the best buildings of our time. The splendid display of "Maillart's bridges" and showings of works of "Frank Lloyd Wright" and "Le Corbusier" will be remembered. The "Textiles Show" grouped together the leading contemporary American designers of handloom textiles. "Power in the Pacific" was an important show after the war, so far as the Navy is concerned. It is hoped that a furniture exhibit will bring an interesting variety to the future series of exhibits.

An important showing of the work of Moholy-Nagy is scheduled for the near future. Hungarian-born Laszlo Moholy-Nagy, 1895–1946, a pioneer participant in the great artistic movement in Europe, gained international fame as a photographer, set designer, non-objective painter and industrial designer. He has contributed to a broader understanding of abstract design by his research and his theoretical writings. Mrs. Moholy-Nagy has loaned part of her collection to the Museum of Modern Art in New York, for circulation. However, at the Hayden Gallery, this travelling exhibit will be enriched by the loan of additional pieces from Mrs. Moholy-Nagy's personal collection.

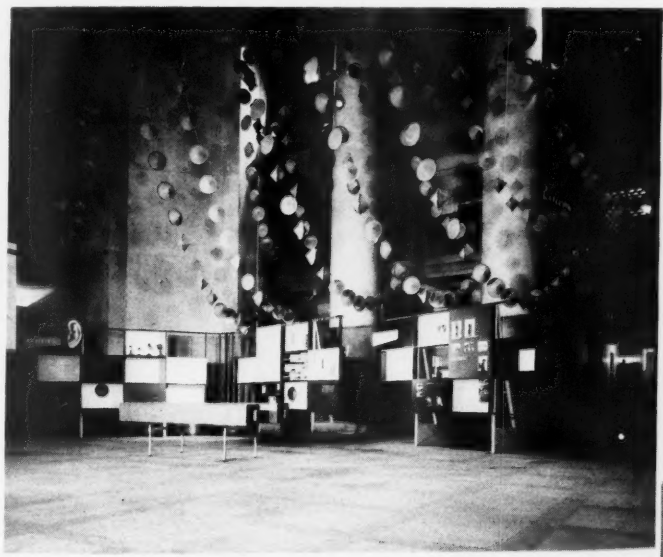
Museums in the Boston area offer a wealth of richness to the surrounding student population. There are assurances that occasional loans will be made from local museums for the new Hayden Gallery. Aside from the inherent value of these exhibits, it is hoped they will encourage student interest in the activities of the large museums.

As a part of M. I. T.'s General Humanities Program, all exhibits are under the direction of the Museum Committee; Professor H. L. Beckwith of the Department of Architecture is director of exhibits. The staff of the Museum has developed, in addition to the short-term exhibits, technological displays of a more permanent nature in appropriate spaces around the Institute. Permanent exhibits are, of course, of greater interest to the occasional visitor.

For instance, the Francis Hart Museum houses a permanent collection of ship models. Remodeled in 1948, it is a thoughtful solution to security and display problems. Models contained in glass cases between structural bays along Building 5 corridor attract the visitor into the space. The interior design is deliberately simple, a quality that heightens the effectiveness of the delicate and colorful models. Some models, supported in space by vertical rods, achieve a three-dimensional freedom seldom realized in similar displays.

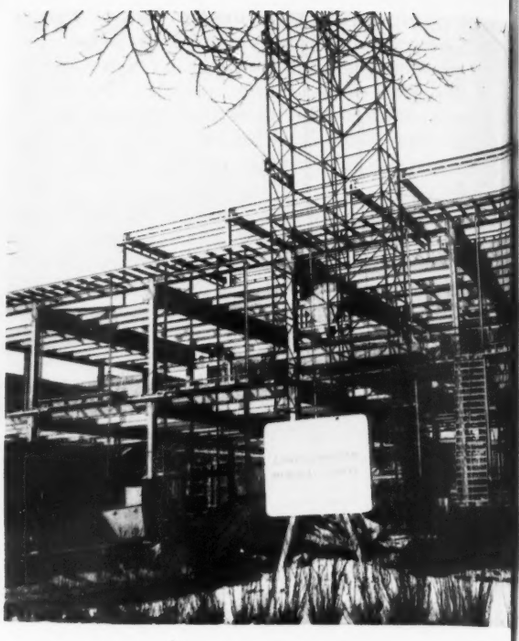
The skillful exhibition technique apparent in the small museum has been soundly praised by Naval Architecture and museum authorities. See for yourself! You can spend a relaxing hour pondering the historic *Constitution*, the *Christianus Quintus* of the seventeenth century Danish Navy with its ninety guns and glittering decorations, and the powerful *U. S. S. Missouri*. Not less revealing is the "Clark collection" of early racing yachts of the period between sail and steam. "The Forbes collection" of ancient maps — French, Italian, Dutch, German, English, Spanish and Portuguese — includes also early astronomical prints and a good coverage of prints on natural history. A rich addition to the musuem was brought lately through the indefinite loan made by the Haffenreffer Family Foundation. By it, the records, models, photographs and original drawings of Captain Nathaniel Herreshoff, one of the great American yacht designers, were turned over to M. I. T. It is hoped that a special exhibition of the collection will appear some time later.

Exhibits at Tech, outstanding in interest, content and method, will continue to grace the Institute — even more attractively than in the past — from the fresh Hayden Gallery. Winston Churchill had no need for cautioning President Killian: "As you advance science at M. I. T., do not neglect the humanities." Chief Justice Holmes' beliefs on civilized man are well taken " . . . he should be able not only to explain but to feel; that the ardour of intellectual pursuit should be relieved by the charms of art, should be succeeded by the joy of life, become an end in itself."

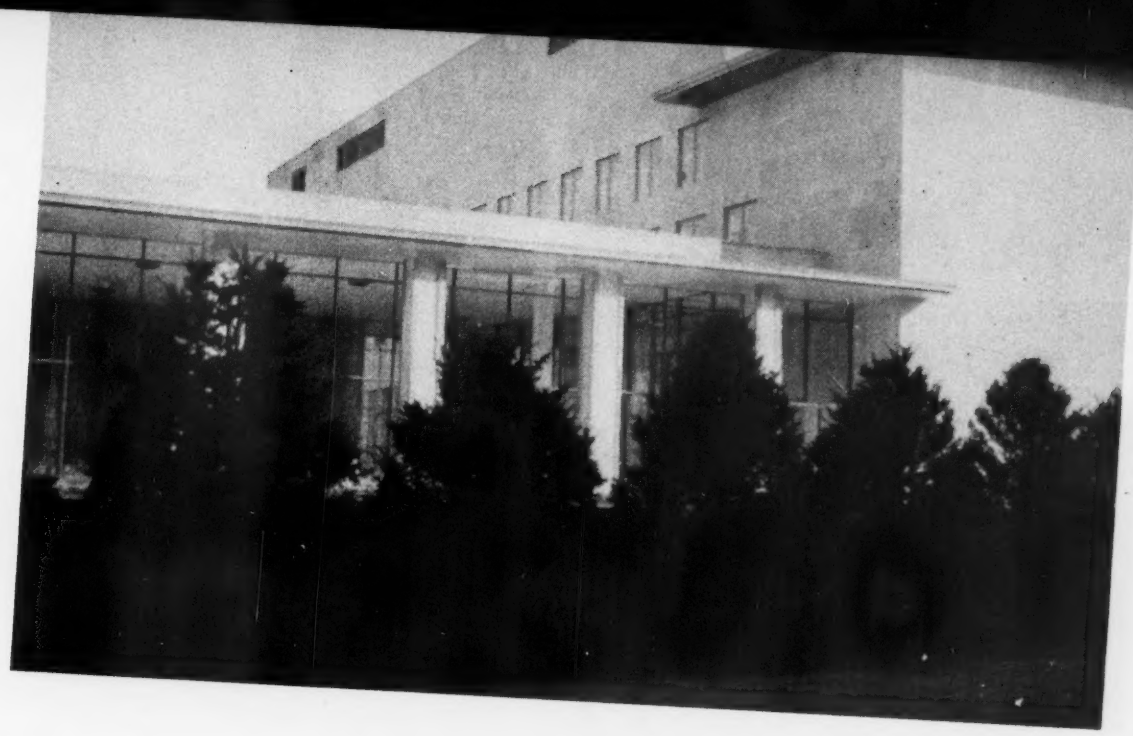


A more informative view of the acoustics exhibit is shown here.

It may not look like much from a distance, but look more closely next time.



The New



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DECEMBER, 1949

tech engineering news

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from the editor's notebook

A Little History? . . .

Tech's philosophy of undergraduate teaching is to teach principles rather than superficial techniques. This is fine — such an education distinguishes the engineer from the technician. There is something missing, though, from a lecture which enumerates laws and their application. Such a procedure gives but a static picture of the subject in hand. Yet engineering and science are obviously growing things; each professional generation builds on the work of the preceding one. Hence a static picture will not do — it implies completeness whereas the goal of our endeavors is progress. Just as important to the student engineer for proper interpretation and application of a principle as its memorized form, is knowing whence it came. Who originated it? To solve what problem? What do we know that modifies its truth? Should not these questions be answered in our classes? To do so is to give an outline of the development from the past to the present — so valuable because it points the way of growth of the future from the present. In graduate work, and in the field, no one attempts original work before learning what has been done before on his problem. Why not introduce into the undergraduate courses, also, an account of how the facts, laws, and methods came to be accepted?

G. B. F.

Watch Next Month . . .

By now most persons have forgotten about the living habits questionnaire circulated in some classes last month, but not *T. E. N.*'s staff. For some time now, it has been putting together the data collected in this poll and promises to have, in the near future, an exposé of how the Tech student spends his time. We hope that the data involved will prove interesting and perhaps provide good material for boasts of how little sleep a Techman gets, how much time he spends doing homework, and how often he goes out. Perhaps there can be found in this data a basis for personal comparison with average values.

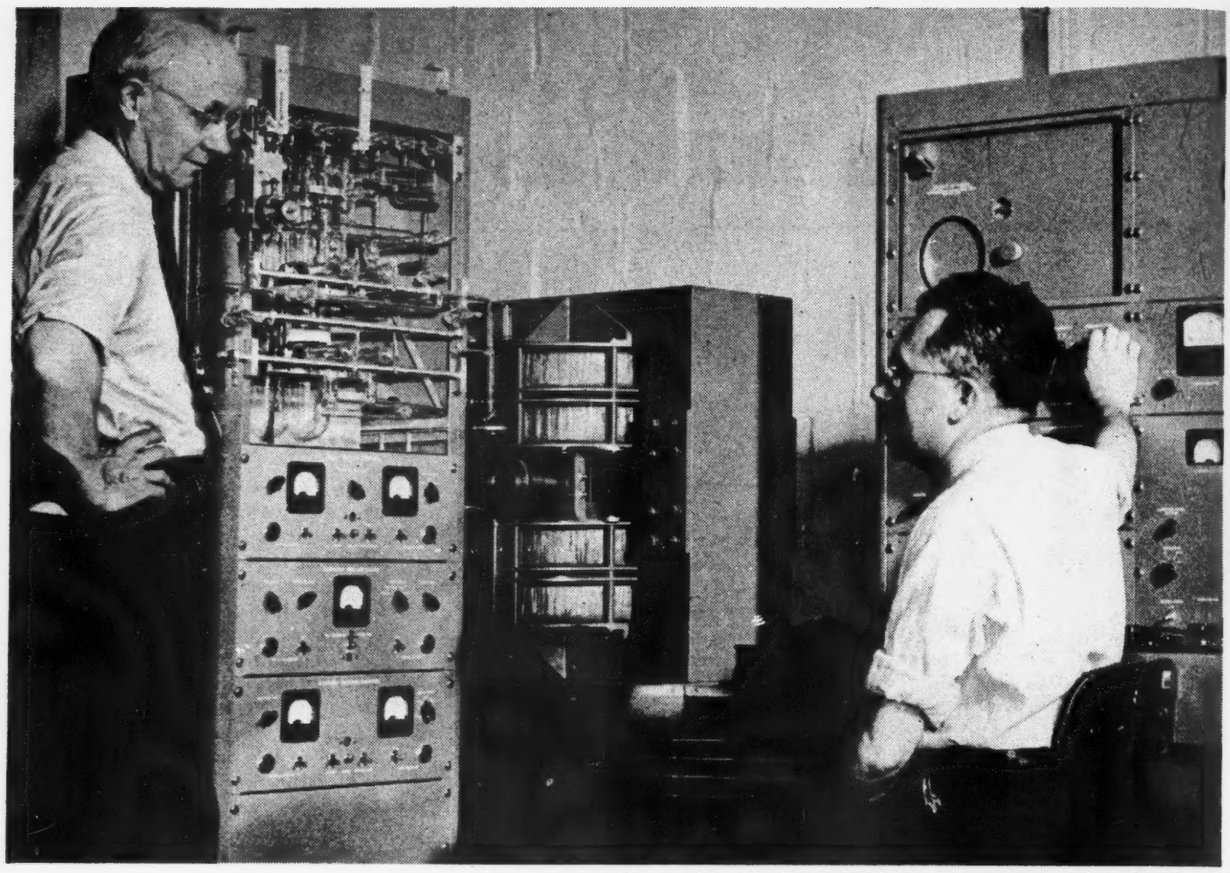
Via Gyrocompass . . .

This issue of *T. E. N.* takes us from the end of the world to the prosaic trolley car, with a short stop for the gyrocompass.

There is forming at Tech a student group which has as its goal the study and furtherance of science fiction. The initiator of this organization, RUDOLPH PREISENDORFER, '52, brought to us a couple of stories which he thought we might like to print. There would be no copyright tangle to unravel because he had dashed them and others off himself. Well *T. E. N.* has wanted to print good science fiction, and Rudy and his group seem able to supply us with a story whenever we want one. We hope to see more of this type of material. If there is anyone really interested in science fiction who has not heard of this new group, may we suggest that he get in touch with Rudy.

For some reason or other, there arrives at our office each month a copy of the magazine *Mass Transportation*. This year we found a staff member to read it. DAVE KLEPPER, '53, holds as his hobby the study of urban transportation systems and, in addition to his work on the makeup staff, has written an article in favor of trolley cars — not the kind that used to run on Mass. Ave., but the so called "streamliners." They have some interesting features which you probably have never heard about.

RAY GHOSN, a graduate student, came to *T. E. N.* in order to help draw covers (last month's issue was the result of his labors), but he did not want to stop at that. He had in mind a couple of articles, one of which you can find in this issue. M. I. T.'s museum system is taken for granted throughout the school; a casual glance in Building Seven and a slight "eyes right" anywhere else is all they usually get, but a good deal of planning is put into each one of them and their value is often underestimated. Ray tells us about the exhibits throughout the school and the future plans of those in charge of them.



New analytical techniques with mass spectrometer, infrared and pod equipment. Refinery Chief Chemist G. Lansing, Washington & Jefferson, '11, Cincinnati '17, J. A. Simpson, N. Y. U. '38, Stevens '43.

What should a man work For?...

Put that question to either of the men shown here, and he'd answer about like this:

"Well, you could say a man works for a living, but there's more to it than just that. A man has his self-respect to keep. He wants to work at a job he likes. He wants to do something useful. He wants fair pay and steady hours—with some time to himself and his family. He wants a chance to get ahead and he wants to save some money. And he wants some security in case of accident or sickness. Then, when his working years are done, he wants to know he can retire on an annuity."

Today, in Esso Standard Oil Company, 28,000 men and women have jobs which offer exactly these things.

They have such jobs because of a company policy that was set up over 30 years ago—and developed side-by-side with our workers ever since. It is a policy based on the belief that the heart of a business is its people—that the best possible jobs attract the best possible workers.

Workers in this company today have everything outlined in the statement above—including vacations with pay, sickness benefits, cash savings in a Thrift Plan, and the opportunity to retire with income for life.

Our 28,000 workers, for instance, have now been with us on the average for 12 years—8,400 of them more than 20 years.

But this policy hasn't grown from "generosity" alone. It's a practical, common-sense *business* policy, and a good one. Because we know that the best way for Esso Standard to help meet the growing oil needs of the world is . . . by doing our best to help our workers get "the things a man works for."

Esso

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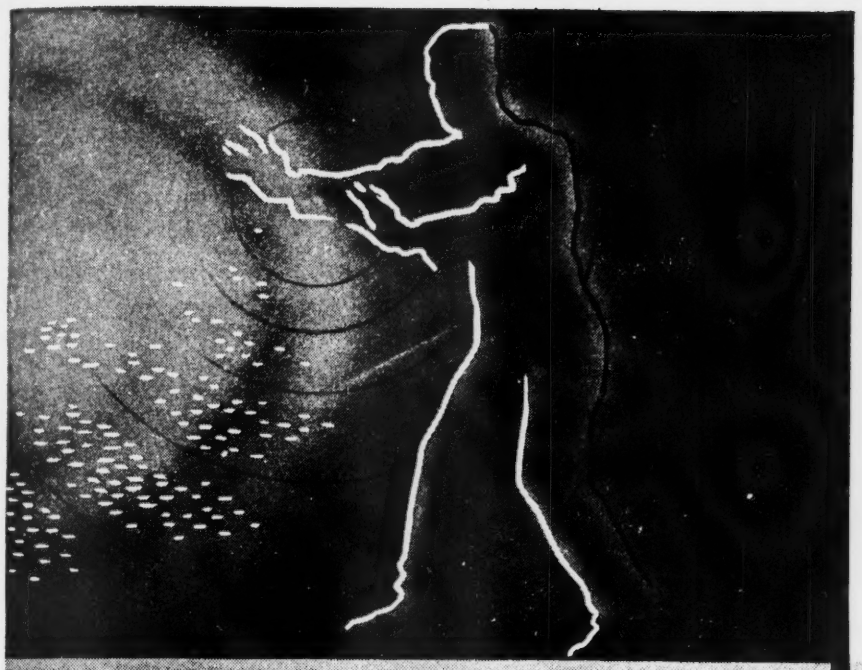

Blind man's buff

Blind man's buff is an expensive game to play with alloy steels. It is safer to go directly to the steel that will give the best performance at the lowest cost per finished part.

Molybdenum steels have shown time and again that they will provide consistently good properties at surprisingly low cost. Even their impact strength is consistent because they are not temper brittle.

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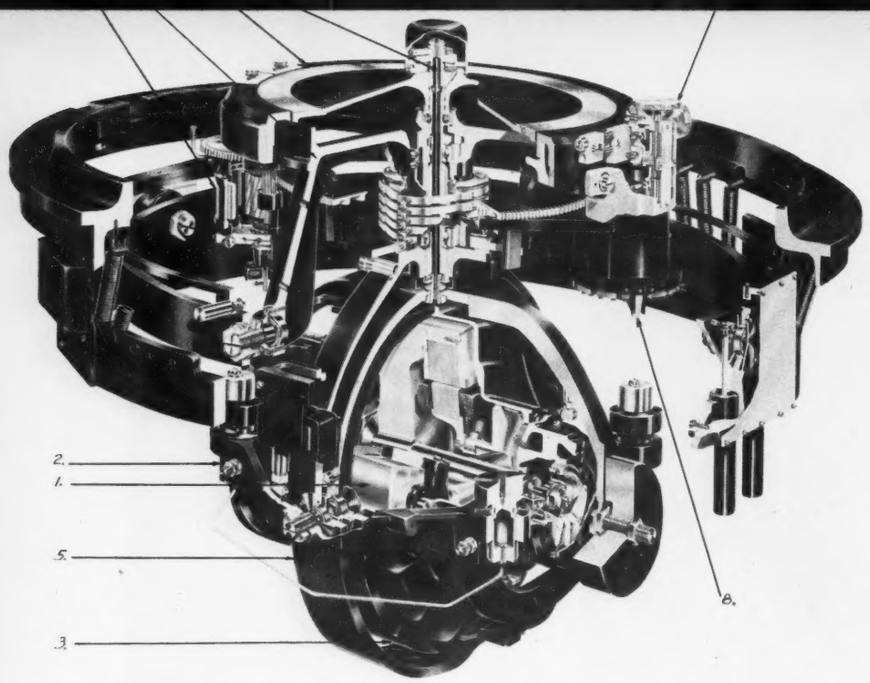

Cutaway view of the Sperry Gyrocompass: 1, rotor; 2, mercury ballistic; 3, vertical ring; 4, steel cable; 5, phantom element; 6, spider element; 7, corrector mechanism; 8, repeater unit; 9, azimuth motor; 10, lubber ring.

meet the gyrocompass

(*Continued from page 9*)

The effect of the pitching and rolling vibrations caused by a rough sea are corrected in the engineering design of the gyrocompass. For proper functioning there must be no torques acting on the principal axis other than those introduced by the proper ballistic tilt. Outside of trivial frictional forces in the bearings, the only possible torques introduced to the principal axis are those produced by the ballistics, and it is imperative, therefore, that no external effects other than the axis tilt act on the ballistics. Since the mercury ballistic is a form of a pendulum the vibrations caused by the ocean waves would tend to excite it and thus introduce unwanted torques on the principal axis. In accordance with mechanical laws, it is known that the amplitude of forced vibrations in a one degree of freedom system is proportional to the frequency of the vibrating force and the natural frequency of the excited object in the following manner:

$$X = \frac{K}{1 - \left(\frac{w_f}{w_n}\right)^2}$$

where X is the amplitude of forced vibrations or in our case the magnitude of the disturbances; w_f is the frequency of the vibrating force — in our case the ocean waves; w_n is the natural frequency of the excited object which is in our case the mercury ballistic; and K is a constant of proportionality dependent on the physical conditions. In accordance with this law it is possible to design a pendulum of such natural frequency that compared with the frequency of the ocean waves would make the amplitude of the disturbance negligible. Our pendulum must also be of such natural frequency as to respond to the earth's rotation. It was primarily to fulfill these requirements that a mercury ballistic was designed. The frequency of the earth's rotation is about 1.15×10^{-5} cps. and that of an average sea wave about .1 cps. By making the orifice in the ballistic through which mercury flows very small, the frequency of the ballistic can be made very small also, and a value was found small enough to obliterate the influence of the sea waves and yet large enough to respond to the earth's rotation.

A commercial gyroscopic compass in wide use today is the Sperry Gyrocompass. The gyro rotor of this compass is kept spinning at a speed of six thousand revolutions per minute by an alternating current squirrel cage motor. The gyro axle revolves in ball bearings carried by the rotor case. The case is supported on horizontal bearings in a vertical ring which is supported from a fine specially designed steel cable, which is in turn fastened to a follow-up system. The follow-up system consists of an azimuth motor which drives a phantom element through the same motions as are transmitted by the steel cable. This phantom element carries the mercury ballistics and by means of the follow-up system keeps them forever in line with the principal axis of the rotor. The follow-up system also serves to magnify the directive force of the gyrocompass, and by means of it repeater compasses and other accessories can be operated from the central station. The phantom is supported by a spider element which constitutes the frame of the compass and through which the current is distributed and controlled. On the spider element are located the lubber ring, the corrector and repeater units.

The accuracy and dependability of the gyroscopic compass, plus the fact that it can be located at any convenient place on steel ships give it a great advantage over the magnetic compass. During the Second World War the gyrocompass was a very essential part of our navy. As a means of defense against magnetic mines a De Gaussing belt was used to reverse the magnetic field of ships, thus rendering the magnetic compass completely obsolete under such conditions. The war demand expanded the fabrication of this intricate device to within the scopes of mass production, and today the gyrocompass is no longer a rare commodity found only in the most expensive liners. As long as the earth rotates and engineering progresses the gyrocompass will play the leading role in the field of navigation while the overworked magnetic compass will eventually join the increasing collection of classical instruments.

In safe hands . . . even at 60 below!

DO YOU REMEMBER when winter meant storing the family car till spring? Not so many years ago, a car owner's fear of an ice-shattered motor was a dread reality . . . if he *didn't* drain his radiator and store his car once cold weather hit!

What was needed—acutely—was an automobile anti-freeze that would prove always *dependable* yet *economical.* One that would hold up under any operating temperature. That wouldn't foam and boil away. That would resist rust and corrosion to the *nth* degree.

That's where Union Carbide *research* entered the picture. The result? "Prestone" anti-freeze. Since then this product —the first all-winter anti-freeze—has assured millions upon millions of motorists of ever-improved driving performance, with assured safety . . . throughout the bitterest weather.

This is but one example of the way the people of Union Carbide are helping to better our daily living. And UCC stands ready to help solve other problems . . . wherever better materials and processes are needed.

FREE: *If you would like to know more about many of the things you use every day, send for the illustrated booklet, "Products and Processes." It tells how science and industry use UCC's Alloys, Chemicals, Carbons, Gases and Plastics. Write for free Booklet 1.*

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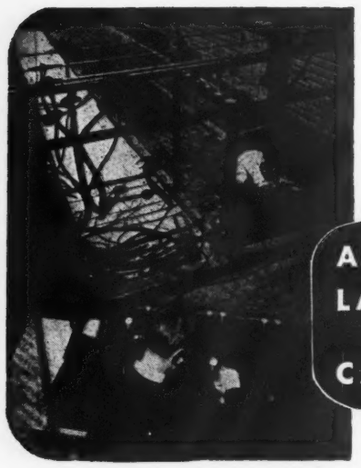


AN OUTDOOR LABORATORY FOR CABLE STUDY

Nothing is guessed at, nothing is taken for granted by the engineers in charge of Okonite's cable proving ground. Buried in various types of chemically different and highly corrosive earth, pulled into conduit or installed overhead, electrical cables are tested under controlled conditions of temperature, voltage and loading conditions duplicating those of actual operation.

In use since 1936, carefully-recorded tests made in this "outdoor laboratory" have disclosed valuable trends. As facts accumulate, Okonite engineers apply their findings to the improvement of their electrical wires and cables. The Okonite Company, Passaic, N. J.

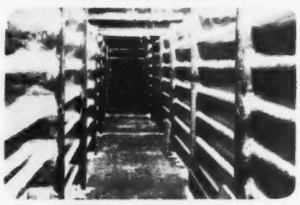
OKONITE
Insulated wires and cables

Cranberry Storage at Sandwich on Cape Cod, Massachusetts

CRANBERRY GROWERS LIKE Frick Refrigeration

And have used it over thirty years!

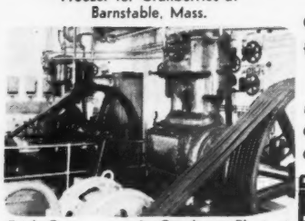
Frick equipment serves this industry in three ways: for short term storage at 32° F; for long-term storage at –5 F; and for freezing the berries to be made into juices—thus carrying the rich color of the skin throughout the liquid.



Freezer for Cranberries at Barnstable, Mass.

The three cranberry plants on Cape Cod use seven big Frick refrigerating machines.

The Frick Graduate Training Course in Refrigeration and Air Conditioning, Operated Over 30 Years, Offers a Career in a Growing Industry.



Frick Compressors in Cranberry Plant at Chatham, Massachusetts

DEPENDABLE REFRIGERATION SINCE 1882
FRICK CO.
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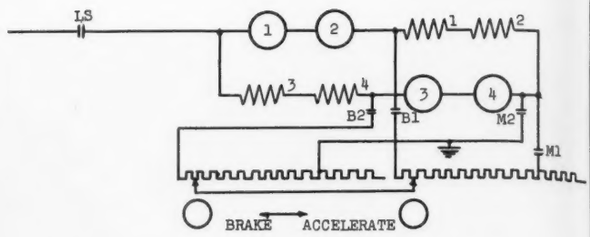
Also Builders of Power Farming and Sawmill Machinery



The basic P. C. C. motor circuit — M1 and M2 are closed upon running; B1 and B2 are closed upon braking.

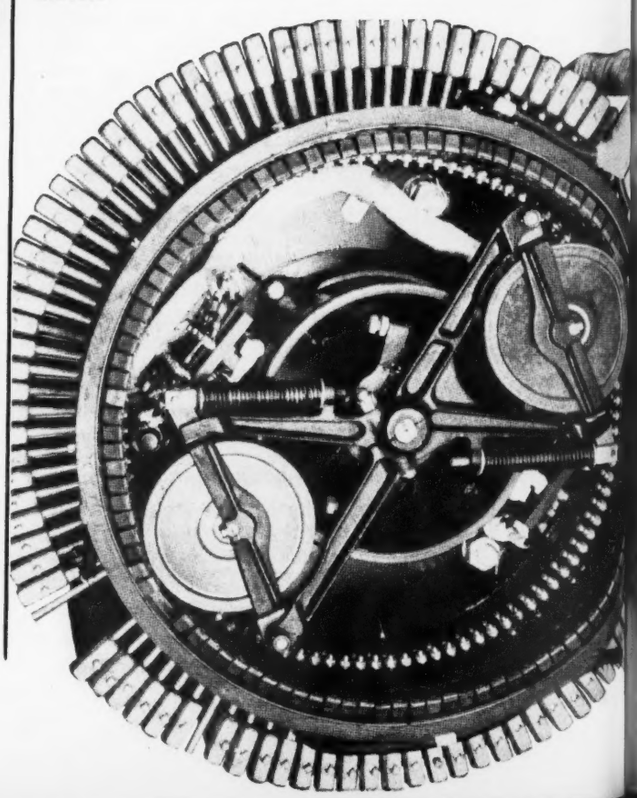
a case for the streetcar

(*Continued from page 11*)

of data printed by the American Transit Association goes far toward proving that P. C. C. cars will give the best returns on the investment they and their operational facilities require, when they are used on any surface route upon which more than four thousand passengers are carried past a given point during the hour of greatest travel. Detroit's Department of Street Railways decided some years ago that all surface trolley operation was to eventually cease and that Detroit was to have an all bus transit system. Unfortunately for those plans, buses would not be delivered fast enough, so that P. C. C. cars were ordered for service on the heaviest line until motor coaches could be delivered. Their performance, efficiency, and high earning power, as compared to that of the automotive buses on Detroit's next heaviest line so impressed the department that it is now receiving an additional one hundred and six P. C. C. cars for service on Detroit's

(*Continued on page 30*)

This automatic accelerator is driven by a pilot motor.



THE DU PONT DIGEST

FOR STUDENTS OF SCIENCE AND ENGINEERING

CARBON MONOXIDE... FRIEND OF MAN

Thanks to high-pressure synthesis, it now leads a useful life

To the man on the street, carbon monoxide is just a poisonous gas that sometimes causes tragic deaths when it escapes from the exhaust of an automobile or from a poorly tended furnace.

Outside of the chemical field, few people are aware that, properly used, it is a very real friend of man. In the last 25 years, during which catalytic

A. H. Emery, Jr., *M.S. Ch.E., M.I.T. '49 and M. J. Roedel, Ph.D. Org., Michigan '40 inspecting a high-pressure batch reactor taken from the shaker tube assembly after a run to make 3,5,5-trimethylhexanol.*

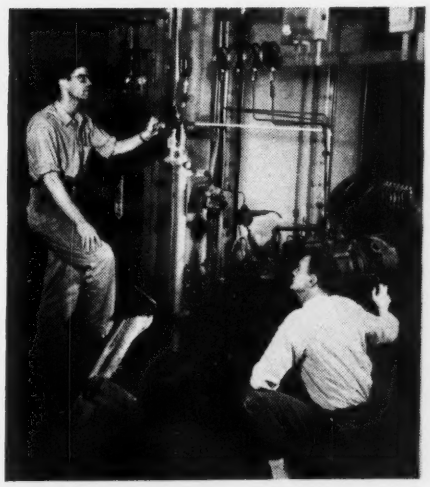
and high-pressure chemical techniques have been highly developed, carbon monoxide has become a keystone of industrial synthesis.

Scientists have found that under the proper conditions of high pressure and temperature, carbon monoxide, in combination with other substances, can be converted to a variety of useful products. These or their derivatives range from an acid used in tanning hides to the sparkling plastics in milady's boudoir.

You'd hardly associate carbon monoxide with anti-freeze. But at temperatures from 300 to 450°C. and under pressures of 1500 to 15,000 pounds per square inch, carbon monoxide and hydrogen unite to form methanol—a colorless liquid from which is made "Zerone" anti-rust anti-freeze for automobiles. From methanol and carbon monoxide as raw materials, ethylene glycol for "Zerex" anti-freeze is produced.

Plastics *and* Anti-Freeze

Methanol is used also to make a large number of compounds such as formaldehyde and methyl methacrylate. The former goes into urea- and phenol-formaldehyde plastics for light fixtures, radio cabinets, hardware, utensils, and electrical equipment. The latter is the basic material for "Lucite" acrylic resin with its many uses.

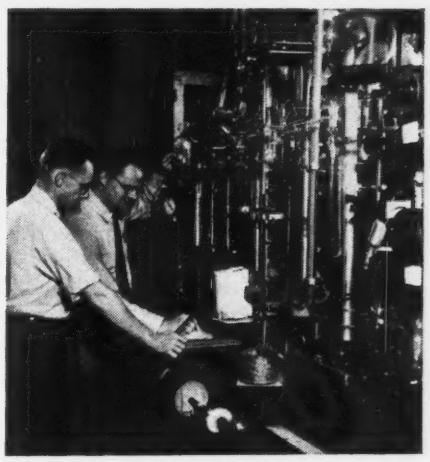


R. L. Stearns, *B.S. Ch.E., Yale '49 and H. Peterson, B.S. Ch.E., Northeastern Univ. '42 checking a multi-stage carbon monoxide compressor used in semi-works operations.*

The reaction of methanol with carbon monoxide leads to acetic acid, which is a well-known industrial chemical. By the same synthesis but substituting ethanol for methanol, propionic acid is obtained. From it come the "Mycoban" sodium and calcium propionates that retard mold and rope in bakery products.

Synthesis in the Future

Today Du Pont manufactures some 120 different items that are partly or wholly dependent upon elevated



A. J. Hill, Jr., *Ph.D. Org., Yale '44 and F. F. Holub, Ph.D. Org., Duke '49 carrying out an experiment on a new method for purifying carbon monoxide. The large furnace in this apparatus operates at 1200°C.*

pressures. However, the possibilities have by no means been exhausted. Just recently, for example, chemists have been learning how to use carbon monoxide in "up-grading" certain petroleum hydrocarbons to give interesting alcohols. One of these, 3,5,5-trimethylhexanol, is prepared from diisobutylene by reaction with carbon monoxide and hydrogen.

College-trained men and women interested in working in this field at Du Pont may share in discoveries as outstanding as any yet achieved.

Because of the wide scope of Du Pont's activities, young graduates in many different fields have opportunities to select the careers that prove to suit them best as their abilities and interests develop.

DU PONT

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...THROUGH CHEMISTRY

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PROBLEM—Every so often, as the commutator segments of large motors wear down, the mica between them must be cut down. Your problem is to work out a tool which permits the undercutting to be done without removing the armatures from the motors.

THE SIMPLE ANSWER—An S.S.White power drive flexible shaft hooked up to an electric motor gives you the basis of a portable power unit for driving small rotary saws. A handpiece designed for mounting the saws finishes the tool. The illustration below shows such a unit made by the Martindale Electric Co., of Cleveland, Ohio.

The time and labor-saving advantages of having an easily manipulated power tool which can be brought to the work, can be readily appreciated. S.S.White flexible shafts make practicable the development of such tools for many purposes.

★ ★ ★

This is just one of hundreds of power drive and remote control problems to which S.S. White flexible shafts provide a simple answer. Engineers will find it worth while to be familiar with the range and scope of these *Metal Muscles** for mechanical bodies.

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St. Louis Car Company photo

Spacious, comfortable interiors of P. C. C. cars win passenger approval.

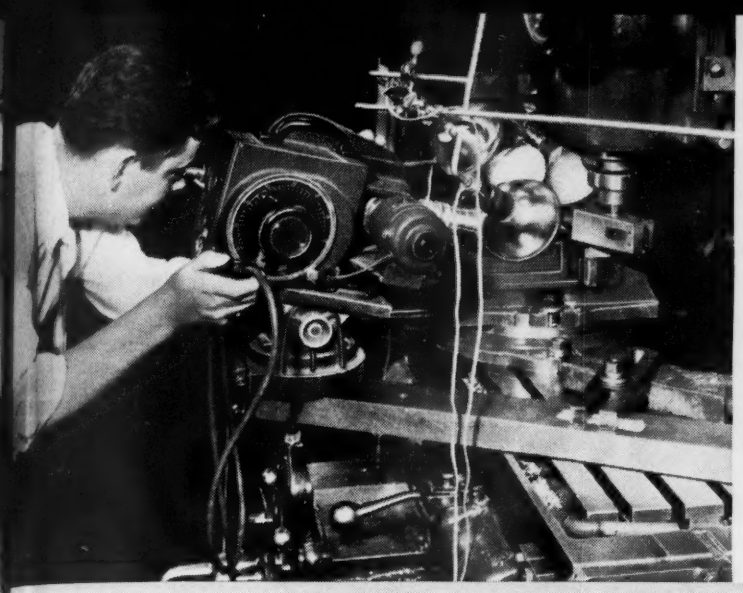
a case for the streetcar

(*Continued from page 26*)

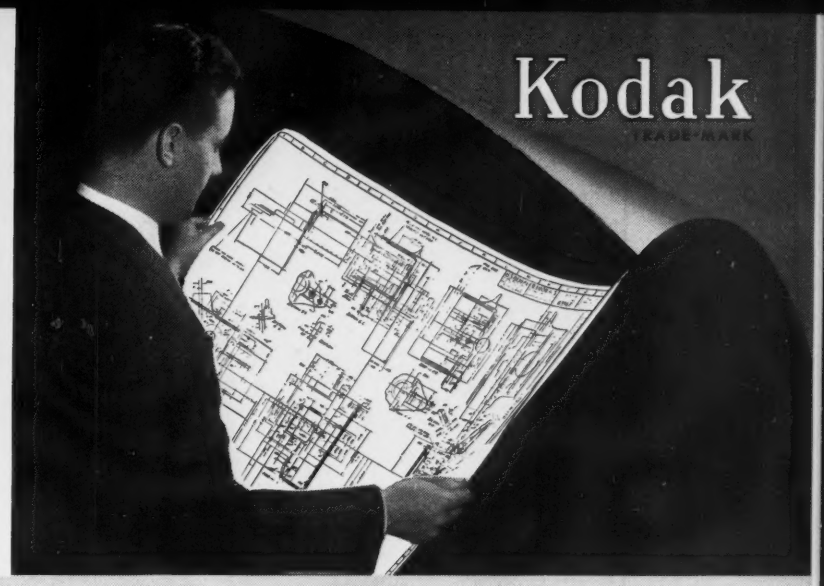
remaining heavy routes. The all bus transit plan has been discarded, and the city will be served by a transit system using P. C. C. cars, trolley buses, and motor buses, each to its best advantage.

Each transit company, including the M. T. A., has its own ideas on what constitutes good practice for utilization of P. C. C. cars, and thus truly unbiased figures on relative costs of operation are hardly possible to attain. Pittsburgh Railways has found practical a high degree of utilization of P. C. C. cars, even on lines whose passengers per maximum passenger hour figures are well below four thousand. The Chicago Transit Authority intends, on the other hand, to retain streetcar service, using P. C. C. 's on only the most heavily traveled lines.

There is one point of supposed superiority of buses over streetcars which has not been mentioned. This is the lack of flexibility due to a fixed track. This is no hindrance to the modern streetcar's moving through traffic; the rapid acceleration more than compensates for that. The fixed track brings with it a reliability under all weather conditions, as well as the smoothness of travel, that is lacking in the flexible routing of the bus. Temporary track across obstructions and even fire hose jumpers are possible on a progressive transit system. The only cause of concern is the thought that the streetcar limits the capacity of a road by blocking auto traffic, especially when stopping in the middle of a street by a loading island. This objection can be answered in three ways. First of all, it is rare to see a bus actually curb load. More often, the bus will pull over with its front some three feet away, and with its rear out in the line of traffic. In swinging from the middle of the street to the curb a bus will cause as much confusion as the streetcar. Second, most of today's traffic experts recommend the segregation of traffic into fixed lanes to increase the capacity of our streets and highways. The streetcar, then, is in a modern trend when it remains in a fixed lane. Last, and most important, we must consider which is more important, the private auto or the mass transportation vehicle. On a one-way street, sixty feet wide, with no parking, only 3700 passengers may ride past a given point in one hour in automobiles only. In both autos and buses, 11,130 passengers can ride past a point. With streetcars and autos, the capacity of the street is increased to 15,650 passengers. It is this large capacity, high efficiency in moving people, that permits P. C. C. cars to actually reduce traffic problems.



IT HELPS IMPROVE PRODUCTS—High speed movies provide a record of motion far too fast to see. With the Kodak High Speed Camera, a second becomes three minutes, so you can see and analyze rapid movement—spot faulty action and points of excessive wear—see ways to make a better product.



IT COPIES DATA IN SECONDS—Engineering drawings, shop orders, specifications, records, and letters of all kinds can be copied fast, and with utmost accuracy. Photocopying with Kodagraph Papers, Cloths, and Film saves time, protects originals from wear and tear—even permits producing clean, legible copies from faded or worn material.

How photography's *Lightning Speed* works for business

HERE YOU SEE a few examples of how the speed of photography serves industry. In addition, its accuracy is used in copying drawings, documents, and data of all kinds. Its ability to reduce can put records on microfilm and save 98% of filing space.

These and the other unique qualities of photography are helping cut costs, improve products, speed production, and stimulate sales. If you would like to know more about how it could serve you, write for literature or for specific information which may be helpful to you. Eastman Kodak Company, Rochester 4, N. Y.

FUNCTIONAL PHOTOGRAPHY
—serves industrial, commercial, scientific progress

IT ANALYZES CHEMICALS IN A FLASH—Spectrography with Kodak Spectrum Analysis Film and Plates quickly determines the composition of almost all materials. It provides a means to make frequent production-line analyses. It can maintain a check on specifications and speed up output.

IT RECORDS THE FLICK OF INSTRUMENTS—The swift swing of the galvanometer mirror or cathode-ray tube beam is not too fast for photography. Readings of these instruments are quickly recorded on Kodak Linagraph Films and Papers so that they can be studied and full advantage taken of the facts that they reveal.

Ever notice the tympanist tightening up the head of his kettledrums before a concert? It's leather plus correct tension that gives him the tone he wants.

In power transmission, leather belt plus tension control is giving industry a drive it wants. The "Uni-Pull" drive combines flat leather belting with a tension-controlling motor base to keep power in tune. It's a modern, compact set-up that handles power as no other belt drive can.

American LEATHER BELTING *Association*

Headquarters for Authentic Power Transmission Data

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Have you heard what they're saying about NE?

Some grad is spreading the word that National Electric is the world's largest single source of supply for electrical roughing-in materials. (And he couldn't be righter!)

Since 1905 NE products have set the pace for quality. Today the NE *complete* line of electrical roughing-in materials includes: wires, cables, conduit, raceways and fittings.

National Electric
PRODUCTS CORPORATION
PITTSBURGH 30, PA.

finite differences

(*Continued from page 12*)

(17) $y_{x+1} = (\Delta + 1)y_x$

as we have seen: $y_{x+1} = (E)y_x$

so we can say that the operators E and $\Delta + 1$ are equivalent:

(18) $E = \Delta + 1$

Then:

(19) $Ey_x = (\Delta + 1)y_x$

or:

(20) $E^n y_x = y_{x+n} = (\Delta + 1)^n y_x$

which gives:

(21) $y_{x+n} = y_x + n\Delta y_x + \dfrac{n(n-1)}{2 \cdot 1}\Delta^2 y_x + \cdots$

as before.

Our newly found operational methods can also be used to find any desired $\Delta_n y_x$ (see 2) for:

(22) $\Delta y_x = y_{x+1} - y_x = Ey_x - y_x = (E - 1)y_x$

or directly: $E = \Delta + 1$ $\qquad \Delta = E - 1$

so:

(23) $\Delta y_x = (E - 1)y_x$

or:

(24) $\Delta^n y_x = (E - 1)^n y_x$

expanding:

(25) $E^n y_x - nE^{n-1}y_x + \dfrac{n(n-1)}{2 \cdot 1}E^{n-2}y_x - \cdots$

using definition of E:

(26) $\Delta^n y_x = y_{x+n} - ny_{x+n-1} + \dfrac{n(n-1)}{2 \cdot 1}y_{x+n-2}$

To derive an interesting special case, let $y_x = x^n$,

(*Continued on page 34*)

EXPLORE

New Frontiers of Industry!

By EDWIN H. BROWN, *Vice President, Engineering Development Division*
Allis-Chalmers Manufacturing Company (*Graduate Training Course 1908*)

WILL IT WORK? Is it practical? Is there a *better* way to do it? If you feel the challenge in questions like these and get a thrill out of finding the answers — perhaps you're cut out for research.

EDWIN H. BROWN

There are a lot of us like that here at Allis-Chalmers. Pioneering beyond the immediate frontiers of industry has been one of the major factors in the growth of this company for over 100 years. Yet today we're finding more exciting frontiers to explore than ever before.

My part in this work started back in 1906 when I joined the Allis-Chalmers

Measuring cavitation resistance of various materials for pumps and hydraulic turbines. Material under test is electronically vibrated at a high rate while submerged in water.

Graduate Training Course, from the University of Nebraska. During my two years in the course, I spent a good deal of time on the test floor. That's the spot where original thinking, new designs, and new methods pay off in results. It's a great vantage-point from which to watch industrial development at work.

After completing my GTC, I worked as a test engineer . . . as development and sales engineer on steam turbines . . . as a chief engineer and department manager . . . and into my present work in research and development.

Unusual Range of Activities

Research here at A-C covers a tremendous range of industrial fields. I might point out that product development is considered a responsibility of each product department, while the central research and development organization works with the many departments in a staff capacity. Since Allis-Chalmers produces important machinery for every basic industry, you can see that our development work is extremely varied.

It includes such things as methods of burning coal deposits underground, to produce power without the intermediate steps of mining, processing and transporting the fuel to power plants. We're developing equipment for the application of atomic power in naval vessels. Working closely with engineers of the Turbopower Development Department, we're developing gas turbines for ship propulsion and high-temperature gas turbines for locomotive service, burning powdered coal.

Other engineers and scientists are engaged in pure physical research into factors that influence power transmission over long lines. There's constant departmental research and product development going on in the fields of flour milling, ore processing, water conditioning, hydraulic turbine design, electronics, new manufacturing methods and techniques, industrial design.

Pick Your Spot

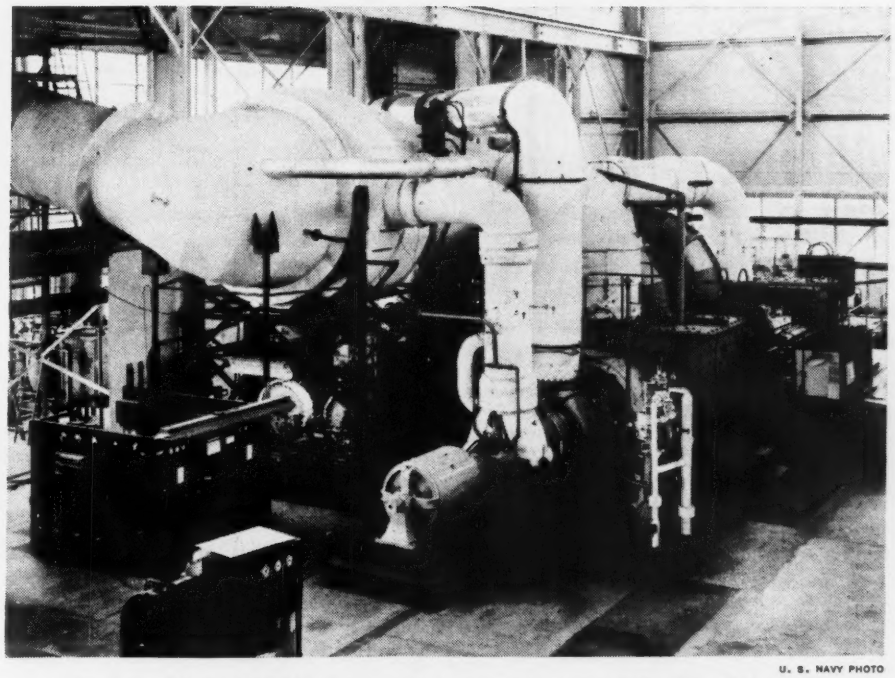
Graduate engineers selected for the Allis-Chalmers Graduate Training Course have a unique opportunity to explore many engineering and industrial fields, and find the work that suits them best. Here, you help set your own course—may change it as you go along and special interests develop. You can gain first-hand experience with almost any major industry you can name—electric power, mining, wood products, hydraulics, public works. You can work in machine design, research, manufacturing, sales engineering. You can earn advanced degrees in engineering at the same time. When you finish the course, you know where you're headed— and you're on your way!

Write for details of the Allis-Chalmers Graduate Training Course—requirements, salary, advantages. Representatives may visit your school. Watch for date.

Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin

A-C ALLIS-CHALMERS

ALLIS-CHALMERS



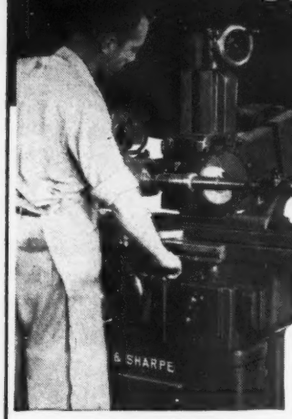
U. S. NAVY PHOTO

Experimental Gas Turbine at Annapolis is shown in new building to which it was recently moved. After extensive testing at progressively higher temperatures, the U. S. Navy unit has now been operated in several tests at its design temperature of 1500° F.

for higher operating efficiency...

NEW DESIGN No. 13

Universal and Tool Grinding Machine



CHECK THESE IMPROVEMENTS

- √ Improved wheel spindle and Headstock
- √ 6 table speeds from 7¾" to 100" a minute
- √ New "bumping control knob for table adjustment
- √ 4 changes of work speed
- √ Automatic lubrication
- √ Built-in electrical controls

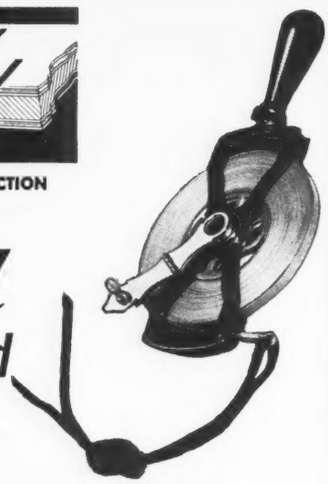
This general-purpose No. 13 Universal and Tool Grinding Machine embodies many outstanding refinements in design and construction for tool-room operations—grinding small and medium-sized cylindrical work, form grinding, sharpening milling cutters, reamers and similar tools and miscellaneous other types of work.

For complete specifications and description of the New Design No. 13, write Brown & Sharpe Mfg. Co., Providence 1, R. I., U.S.A.

BROWN & SHARPE B·S

DIAGRAMMATIC CROSS-SECTION VIEW OF A

LUFKIN Chrome Clad Steel Tape



This cross section view gives you the "inside story" of the most outstanding development in steel tapes in years. (1) Hardened steel tape—tough—flexible—kink-resistant. (2) Rust resistant coating. (3) Multiple coats of electroplating. (4) Hard, smooth, non-glare chrome plating. Will not crack, chip or peel. (5) Jet black markings—easy to read in any light—bonded to steel base—sunk below chrome surface protecting them against wear.

Ask your distributor for them or write for complete details on Lufkin Chrome Clad "Super Hi-Way," "Pioneer," and "Michigan" Chain Tapes.

THE LUFKIN RULE CO.
SAGINAW, MICHIGAN
PRECISION TOOLS — TAPES — RULES

EASY TO READ MARKINGS THAT ARE DURABLE

finite differences

(*Continued from page 32*)

then:

(27) $\Delta^n y_x = \Delta^n x^n =$

$$(x+n)^n - n(x+n-1)^n + \frac{n(n-1)}{2\cdot 1}(x+n-2)^n \cdots$$

If $x = 0$

(28) $$\Delta^n 0^n = n^n - (n-1)^n n + \frac{n(n-1)}{2\cdot 1}(n-2)^n \cdots$$

Now, going back to the original example, the x^3 sequence, we noticed that $\Delta^3 x^3$ was equal to 3! and in general, (28a), $\Delta^n x^n = n!$ whatever the value of x. Equating (28a) and (28) we get a series for $n!$. This can be used to show that $1 + (n-1)!$ is divisible by n, whenever n is divisible only by itself and one (n is prime).

It has already been pointed out that the infinitesimal and the finite calculus are closely related. An extremely interesting operational equivalence exists between the two; in other words, our goal is now to express E, and Δ in terms of $D = \frac{d}{dx}$. Even the freshmen are by now familiar with the fact that most of the elementary functions like exponentials, logs, and sines, etc. can be expressed in terms of a power series such as:

(29) $$f(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \cdots$$

where $a_0 \cdots a_n$ are constants.

Now:

$$f(x+1) = a_0 + a_1(x+1) + a_2(x+1)^2 + a_3(x+1)^3 \cdots$$

Also:

(30) $$\frac{df(x)}{dx} = Df(x) = a_1 + 2a_2 x + 3a_3 x^2 + \cdots$$

$$D^2 f(x) = 2a_2 + 6a_3 x + \cdots$$

$$D^3 f(x) = 6a_3 + \cdots$$

The reader can easily verify for himself that:

(31) $$f(x+1) - f(x) = Df(x) + \frac{1}{2\cdot 1} D^2 f(x) + \frac{1}{3\cdot 2\cdot 1} D^3 f(x) + \cdots$$

so:

(32) $$f(x+1) = f(x) + Df(x) + \frac{1}{2\cdot 1} D^2 f(x) + \cdots$$

This last expression can again be symbolically factored to give:

(33) $$Ef(x) = f(x+1) = (1 + D + \frac{1}{2\cdot 1} D^2 + \frac{1}{3\cdot 2\cdot 1} D^3 \cdots) f(x)$$

But the series in parenthesis is the power expansion of e^D (Phillips, Calculus, p. 318) so (33) may be expressed:

(34) $$E f(x) = e^D f(x)$$

We may therefore write the symbolic relation:

(35) $$E = \Delta + 1 = e^D$$

Taking the natural log: $ln(\Delta + 1) = D$

But $ln(\Delta + 1)$ can be expanded as a power series in Δ (Phillips, p. 323)

(36) $$D = \Delta - \frac{\Delta^2}{2} + \frac{\Delta^3}{3} - \frac{\Delta}{4} + \cdots$$

So we have at last an equation for the derivative of a function in terms of its differences.

Example: at $x = 4$, the derivative Dx^3 is $3x^2 = 48$. Using (1) for values of $\Delta^n x_4^3$ we have

(*Continued on page 36*)

These glass eggs make TNT behave

The traditional way of shooting an oil well is to lower cans of nitroglycerin into the hole and explode them at the depth where traces of oil have been found.

Now, petroleum engineers, using double-ended glass cones made by Corning, can shape and direct these explosions to penetrate oil-bearing rock with a rifle-like charge.

These pointed glass eggs, with shells no thicker than a pop bottle, are set in the ends of cylinders of TNT and the charges are arranged in a case for lowering into the well.

Miraculous as it may seem, the glass egg—as it is liquefied by the explosion—acts as a gun barrel to aim the tremendous blast and concentrate it in a thin stream. The TNT charge—shooting directly outward—rips a hole in the rock to let the oil flow.

And this hole penetrates some sixteen times farther than one made by an unshaped charge.

Because they are sometimes used in wells two miles or more deep, these Corning glass charge-directors are built to withstand heavy subterranean pressures.

And although the eggs are hollow, they'll stand up under a pressure of 20,000 pounds per square inch.

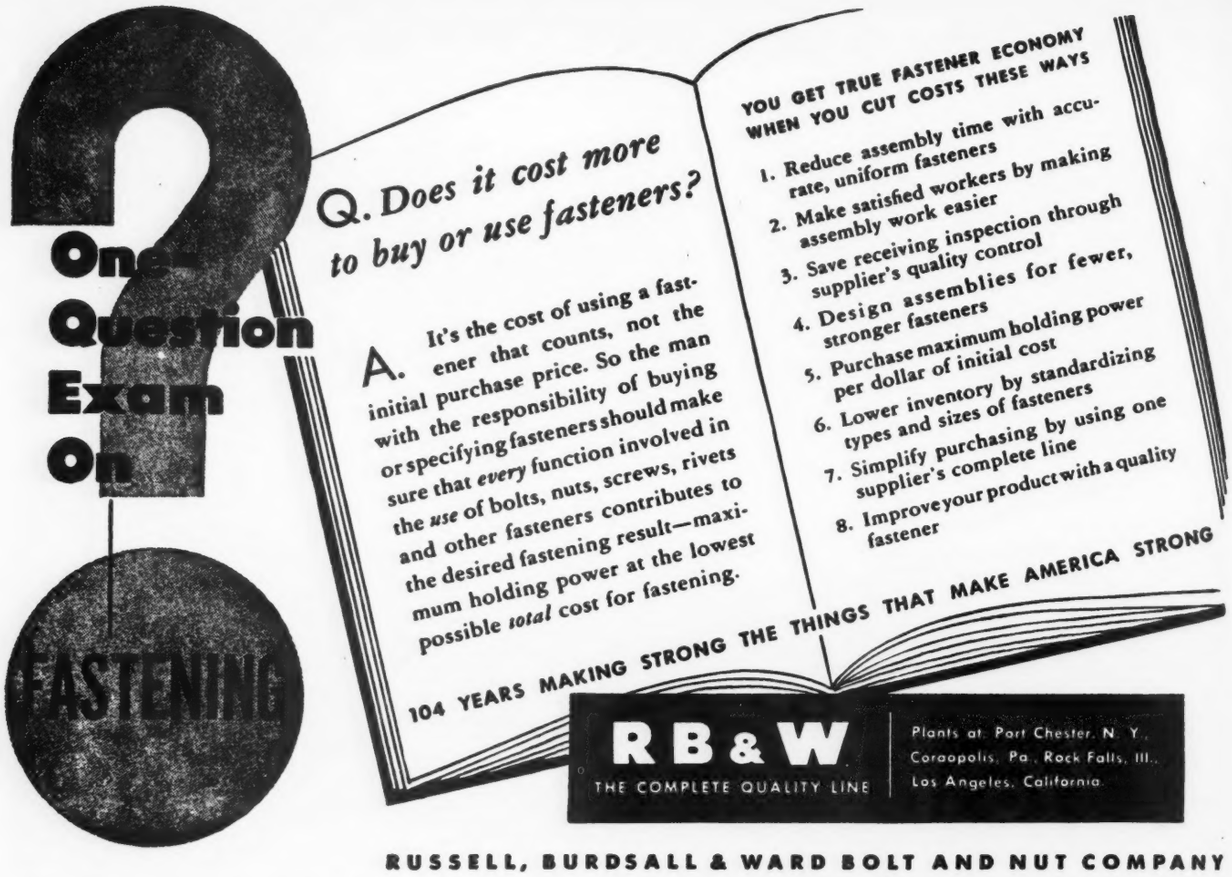
But if that seems strong to you, we'd like to point out that a one-inch cube of this same glass has a compressive strength of 250,000 pounds.

Throughout industry, *Corning means research in glass* because a multitude of Corning developments—such as finding ways to increase its strength—have helped make glass one of today's most versatile engineering materials.

You'll find—when you're out of school and concerned with planning new products and processes, or changes in old ones—that it's a good thing to keep *glass* in mind.

Then, we hope you'll call in Corning before your planning reaches the blueprint stage—to learn how this material, which has so many varied uses, can best serve you. *Corning Glass Works, Corning, New York.*

CORNING
means research in glass


One Question Exam On FASTENING
Q. Does it cost more to buy or use fasteners?
A. It's the cost of using a fastener that counts, not the initial purchase price. So the man with the responsibility of buying or specifying fasteners should make sure that every function involved in the use of bolts, nuts, screws, rivets and other fasteners contributes to the desired fastening result—maximum holding power at the lowest possible total cost for fastening.
YOU GET TRUE FASTENER ECONOMY WHEN YOU CUT COSTS THESE WAYS
1. Reduce assembly time with accurate, uniform fasteners
2. Make satisfied workers by making assembly work easier
3. Save receiving inspection through supplier's quality control
4. Design assemblies for fewer, stronger fasteners
5. Purchase maximum holding power per dollar of initial cost
6. Lower inventory by standardizing types and sizes of fasteners
7. Simplify purchasing by using one supplier's complete line
8. Improve your product with a quality fastener
104 YEARS MAKING STRONG THE THINGS THAT MAKE AMERICA STRONG
RB&W
THE COMPLETE QUALITY LINE
Plants at: Port Chester, N. Y., Coraopolis, Pa., Rock Falls, Ill., Los Angeles, California
RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

finite differences

(*Continued from page 34*)

$$(37) \qquad x = 4;\ D(x^3) = \Delta x^3 - \frac{\Delta^2 x^3}{2} + \frac{\Delta^3 x^3}{4} - \frac{\Delta^4 x^3}{4}$$
$$= 61 - 15 + 2 - 0 + 0 \cdots = 48$$

From the basic similarities previously pointed out between the finite and infinitesimal calculus and the operational relationships just derived, a great parallel structure can be built up. To give an indication of some of these parallels it might be well to end our introduction with a look at finite integration. Suppose a series:

$$(38) \qquad v_x = u_a + u_{a+1} + \cdots + u_{x-1}$$

where v_x and u_x are functions of x and u_a, u_{a+1}, etc. are constants.
Adding another term:

$$v_{x+1} = u_a + u_{a+1} \cdots + u_{x-1} + u_x$$

subtracting:

$$(39) \qquad v_{x+1} - v_x = u_x$$

We have then $\Delta v_x = u_x$. It is now possible to define the operator Δ^{-1} which is the inverse of Δ. This is usually written:

$$(40) \qquad \Delta^{-1} = \Sigma; \qquad v_x = \Sigma u_x + c \qquad c = \text{constant}$$

completely analogous to: $y = \int f(x)dx + c$
Since we have defined v_x as the sum of a series and succeeded in expressing it as a function of its members u_x, we have developed a shortcut to addition. The problem is now this: given any function $u(x)$, of what function could it be the Δ? This is easily determined by analytic formulae somewhat like those developed for integration.

For those interested in a more exhaustive treatment of the topic, Boole's "Finite Differences" ought to be a great help although the formulae come thick and fast with muddled explanation for the most part. The subject has lain fallow for many years now although scientists and mathematicians constantly, and unknowingly, draw upon it when they interpolate or use approximate integration.

day, the eighth

(*Cont. from page 13*)

Twice about the sun it went. An intricate lattice of fine, hairlike furrows were etched upon its surface . . . etched with geometrical precision.

The atmosphere came first.

It just came.

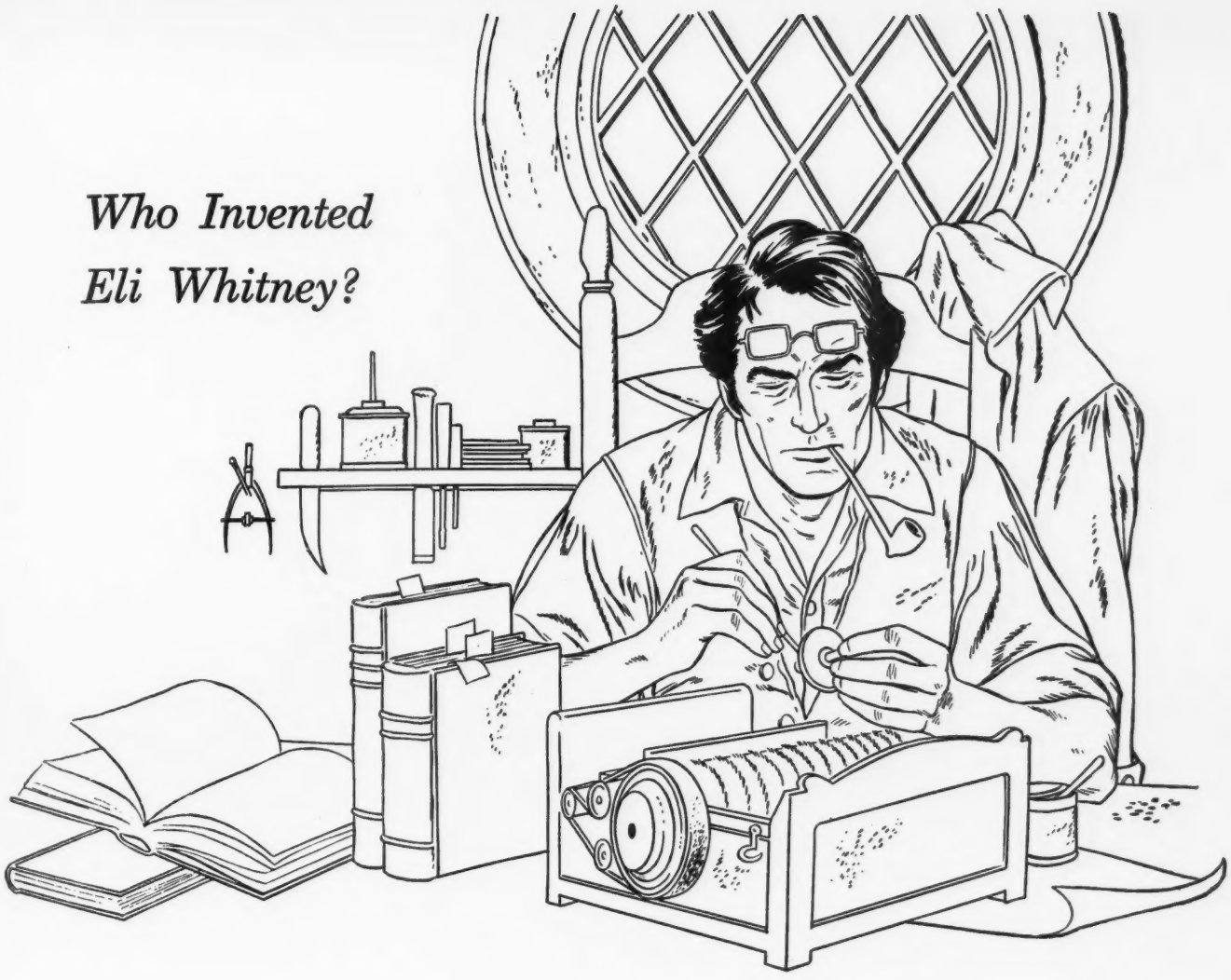
It shone with a bright orange hue beneath the watching eye of the sun. The lattice network upon the face of the Earth was filled with a clear, orange liquid. Between the hair-thin furrows appeared arrays of gleaming silver hemispheres, filling the smoothened surface in rectangular order. Within the bubbles appeared towering structures. Within the structures appeared living beings.

Life went on.

A shimmering silver sphere hung above the brightly colored gaseous shell of the renovated Earth. Within it, moving in the artificially lighted orange atmosphere, was the crew, inspecting its handiwork on the world below. It saw that its work was good, and so it turned in a graceful arc and sped into the depths of space toward the glowing spark that was its mother star.

. . . as simple as that.

Who Invented Eli Whitney?



In 1793 Eli Whitney helped a growing nation take another step in the direction of greatness. Inventions like his made and keep America great. But what does the greatness of American inventors and technology prove?

It proves that Americans are better trained than other people in the scientific and technical fundamentals so necessary for the continuing progress that has kept America the world's greatest nation. In America, the finest textbooks are available to all. This is the background for the technological advances that raise one country above all others.

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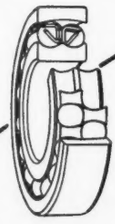

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can you do it?

An American destroyer was sent on a sub killing mission during the Pacific War. Early one misty morning an alert radioman on the destroyer picked up a message being sent in code. The code was one which had earlier been broken, so the radioman eagerly deciphered the message. Apparently from an enemy submarine to its base, the message ran: "Rudder jammed, one engine out. Straight course only possible. Will proceed at maximum speed (ten knots)." There was then some information about course direction which could not be decoded. Even as the crewman handed the captain this message the sub was spotted astern through the mist. The destroyer wheeled to make a run as the men went to battle stations. But in the confusion the prey was lost, nor could the lookouts agree on its direction when last seen. The captain, an old sea dog, gave orders to search the whole area at high speed, hoping to intercept the enemy by luck. After some thought, and some doodling on charts, the first mate proposed a plan by which the ship would definitely catch the sub. What was his plan?

Scientists at RCA Laboratories solve exacting problems within the "nothingness" of vacuum tubes.

Inside story of Better Television

Now television is flashing *visual* entertainment, news, and educational material to millions of people daily. The "inside story" of its rapid growth is the history of some remarkable tubes. Inside these tubes, electrons are put to work—to perform, for your benefit, the miracle of long-distance vision.

The screen of your direct-view television receiver is actually the face of a tube—the kinescope developed by Dr. V. K. Zworykin and his colleagues of RCA Laboratories—on which electrons in motion "paint" pictures. A tube, too, is the "eye" of RCA's Image Orthicon television camera, which can "see" clearly by the light of a match.

And since you asked for big-picture television, they developed projection receivers—also a way to "weld" glass and metal, thus speeding the production of 16-inch direct-viewing tubes . . . at lower cost.

To these basic "firsts," RCA scientists have added advance after advance, which are daily bringing television into the lives of more and more people.

How you profit

Advanced research in television tubes is just one way in which RCA Laboratories work in your interest. Their leadership in science and engineering adds *value beyond price* to any product or service of RCA and RCA Victor.

Examples of the newest advances in radio, television, and electronics—in action—may be seen at RCA Exhibition Hall, 36 West 49th Street, N. Y. Admission is free. Radio Corporation of America, Radio City, New York 20.

Continue your education with pay—at RCA

Graduate Electrical Engineers: RCA Victor—one of the world's foremost manufacturers of radio and electronic products—offers you opportunity to gain valuable, well-rounded training and experience at a good salary with opportunities for advancement. Here are only five of the many projects which offer unusual promise:

- Development and design of radio receivers (including broadcast, short wave and FM circuits, television, and phonograph combinations).
- Advanced development and design of AM and FM broadcast transmitters, R-F induction heating, mobile communications equipment, relay systems.
- Design of component parts such as coils, loudspeakers, capacitors.
- Development and design of new recording and producing methods.
- Design of receiving, power, cathode ray, gas and photo tubes.

Write today to National Recruiting Division, RCA Victor, Camden, New Jersey.

Also many opportunities for Mechanical and Chemical Engineers and Physicists.

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World Leader in Radio—First in Television

Isn't Tommy LUCKY!

Tommy went to a school in the middle west, with hundreds of other bright-eyed youngsters.

One day there was a fire in Tommy's school . . . from defective electric wiring. The schoolhouse was "fireproof", but the contents weren't. So the flames spread, until the whole school was ablaze like a roaring "fireproof" furnace.

Tommy managed to get out. He was badly burned, but he was far more fortunate than some.

That fire was one of five school fires that occur each day, and will continue to occur as long as there are worn and faulty equipment and human carelessness. Regardless of whether a school is constructed of "fireproof" materials, there seems to be no sure way to prevent some fires from *starting.*

But there is a practical and absolutely dependable way to *control* fires before they do material damage.

A Grinnell Automatic Sprinkler System stops fire immediately, automatically, wherever and whenever it strikes. Seventy years' experience shows that this protection is close to 100% effective.

LOOK FOR THE GRINNELL SPRINKLER HEADS ON GUARD!

In schools, hotels, theatres, factories and hospitals there is a moral obligation upon management for the utmost in protection of life and property. For your own sake ask about it in the schools you attend, the hotels where you stop, the theatres to which you go. *Everywhere* you go, look for the famous Grinnell Sprinkler Heads —your assurance of dependable fire protection. Grinnell Company, Inc., Providence, R. I.

GRINNELL

FIRE PROTECTION SYSTEMS

ENGINEERING GRADUATES HAVE FOUND ATTRACTIVE OPPORTUNITIES WITH GRINNELL.

"Magnet Wire? I didn't even know ROEBLING made it!..."

THIS VISIT to just one of the Roebling works has been an eye-opener. Everyone in my line knows Roebling wire rope, but I never heard that you stack up so big in electrical wires and cables."

☆ ☆ ☆

Many people are surprised to learn of the wide diversity of Roebling's line of wires and wire products. It is often news, too, that several different items in the Roebling line are used in one and the same field. In mines and quarries, for example, Roebling Wire Rope, Aggregate Screens and Portable Electrical Cable are all likely to be on the job together. Wherever there's industry, there are Roebling products that help bring highest efficiency and lowest service cost.

WOVEN WIRE FABRIC. Roebling weaves wire screens to meet every sort of industrial requirement. From large size Aggregate Screens to closely woven Filter Cloths, wires made of special steels and non-ferrous metals bring new measures of resistance to abrasion and corrosion.

WIRE ROPE. Roebling wire rope is made in a complete range of types and always affords a rope that's *right* for every application. For easy handling, smooth operation and long life on the job, Roebling Preformed "Blue Center" Wire Rope is unsurpassed.

ELECTRICAL WIRE — CABLE — MAGNET WIRE. With more than 60 standard types, Roebling's line of electrical wire and cable meets practically all transmission, distribution and service needs . . . The insulation of Roevar Magnet Wire is 10 to 40 times tougher than other types — first choice for high-speed winding.

ROUND—FLAT—SHAPED WIRE. Manufacturers adopt Roebling high carbon wire for its dependable uniformity which minimizes machine stoppages and rejects, and pulls down production costs.

☆ ☆ ☆

Whatever career you are studying for, when you get on the job you will find one or more types of Roebling products serving there, dependably and at low cost. John A. Roebling's Sons Co., Trenton 2, N.J.

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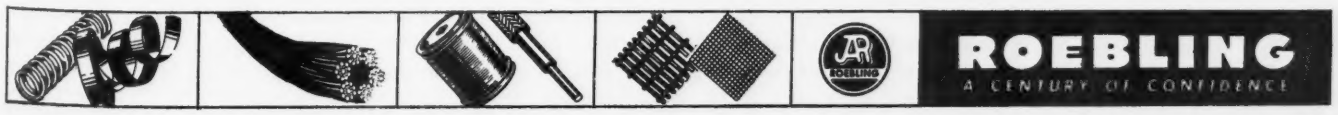


briefing the news

Elastic Cast Iron . . .

Industry now has available to it a new cast iron which, unlike ordinary cast iron, is not brittle but can be bent or twisted. This new material, popularly known as ductile cast iron, can be made readily and economically and has several times greater strength than ordinary cast iron with greatly increased ductility and shock resistance. The potential applications of this novel material are many and varied, and new fields will be opened up because of its excellent engineering properties.

This new ductile cast iron combines processing advantages of cast iron, such as fluidity, castability and machinability, with many of the product advantages of steel. The essential feature of the new process for making this material is the introduction into and the retention by the molten iron under treatment of a small but effective amount of magnesium. The presence of critical amounts of magnesium in the novel cast iron produces a new graphite structure which is in the form of spheroids or compacted particles. Due to the elimination of a substantial amount of the usual weakening flake graphite, the new magnesium treated cast iron possesses excellent engineering properties, particularly high tensile strength, elastic modulus, yield strength, toughness and ductility. Under stress it behaves elastically like steel rather than like cast iron, having proportionality of strain to stress up to high loads with a modulus of elasticity of about twenty-five million pounds per square inch.

The material's outstanding strength and ductility, plus resistance to shock, are especially significant and useful to many industries. More than forty companies are already producing ductile cast iron, and more are being added to this number every day. As much as seven hundred thousand pounds of the material have been made in one day by a single company, and large castings requiring the pouring of fifty thousand pounds of magnesium treated molten metal for each casting have been produced utilizing the technique of this new development.

Metal Films . . .

Metal films, so thin that they can be used as supporting membranes for electron microscopic studies without showing visible structure, are made by a new glycerine-utilizing process. In this process, a piece of glass is covered with a thin layer of water-free glycerine and placed in a vacuum chamber where a small amount of beryllium or aluminum is flash-evaporated. The glass carrying the glycerine and metal film is transferred to a vessel and washed with distilled water; the metal film being floated off the surface of the water. Glycerine was selected because it displayed the requisite properties of a high boiling point and low vapor pressure at room temperature.

Ultra-Violet Microscope

An ultra-violet microscope for observing living, unstained body tissues is now in production. The instrument's objectives not only provide increased resolving power but make it possible to photograph as well as view for the first time freshly prepared sections of live tissue cultures through three different ultra-violet wavelengths. The photographs may also be projected or reproduced on color film through three visual color filters which provide densities, contrast and structural detail never before attained.

The microscope's objectives are of a reflecting type, and therefore corrected chromatically throughout the entire ultra-violet and visible spectrum. All of the elements, mirrors and lenses have simple spherical surfaces. Focusing can be done in visible light and photographs taken with other regions of the spectrum without disturbing the focal setting. By using a band of wave lengths, intensity of illumination in the image is made high, allowing shorter photographic exposure than is required in a monochromatic objective system.

Now in use at M. I. T., the microscope is particularly useful in the field of biochemistry for direct photographic recording of tissues, for microphotometric determination of biochemicals, or for photodensitometry.

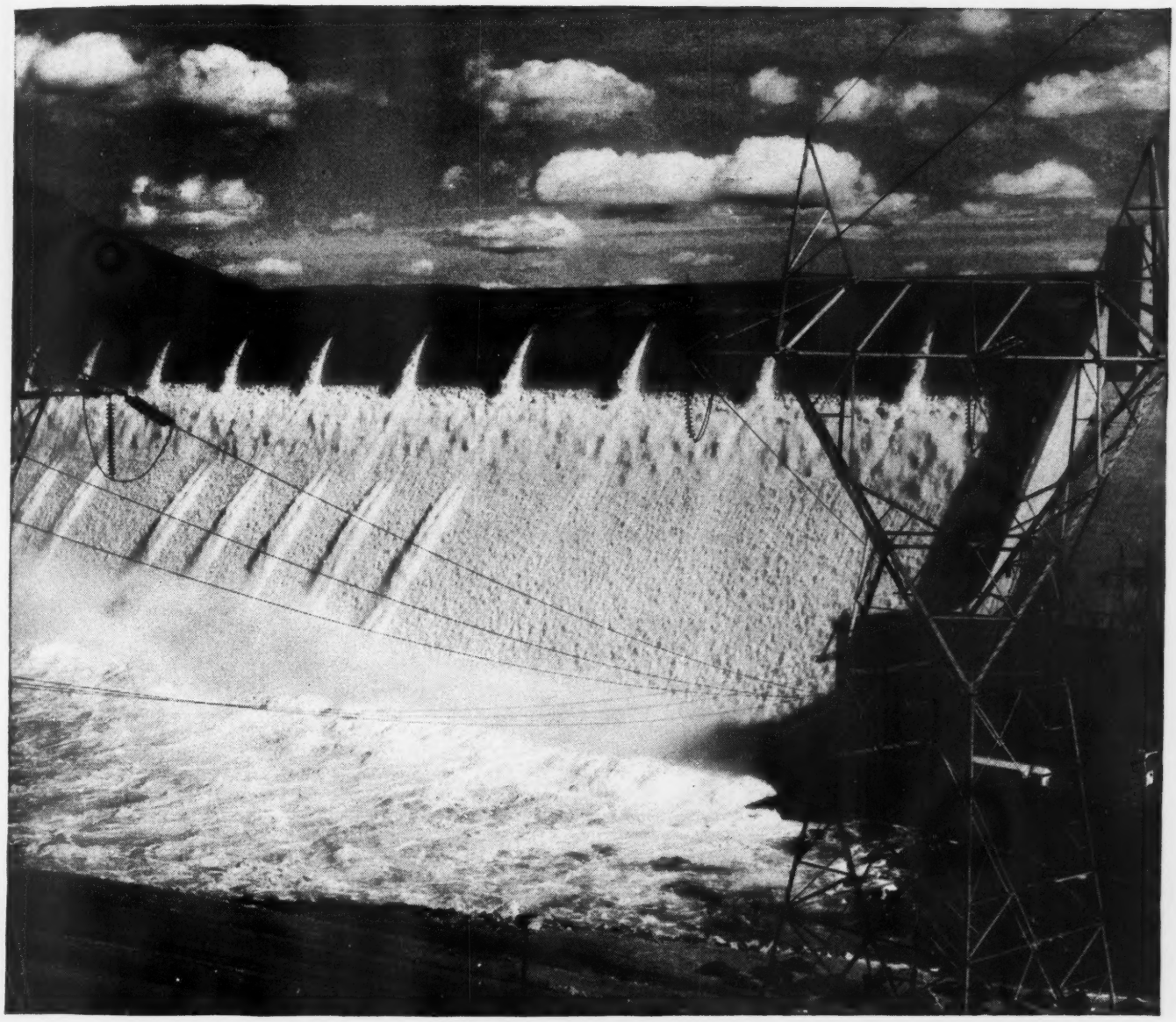
X-Ray Microscope . . .

An X-ray microscope which makes visible internal details of materials through which light cannot pass has recently been constructed. It is still in the laboratory stage.

The instrument may compete with the electron microscope, the most powerful magnifier in use today. The X-ray microscope would have the advantage that the samples being observed by it would not have to be in a high vacuum. It might then be possible to study living materials at higher magnifications than have heretofore been possible.

The microscope operates on the principle that X-rays can be reflected from polished surfaces, provided that the rays strike the surface at very small angles.

Making the "juice" that makes life easier!



DIRECTLY and indirectly, the average family in America consumes more electricity yearly than families in any other country in the world. The demand for more "juice" has grown with unbelievable rapidity, and it's *still* growing. By 1955, the electrical generating capacity of our nation is expected to reach 90 million kilowatts!

Steel is a vital material in the production of electricity. Central power stations and great power dams are made of steel and concrete. Special steels are required for turbines and other generating machinery. Steel towers carry steel-reinforced transmission lines across mountain and prairie alike.

Helping to meet America's constantly growing demands for more "juice" is only one of the big jobs ahead for United States Steel. There are many others. And they all call for the services of thousands of carefully-trained, technical specialists. For steelmaking today is a precision operation, as dependent for success on the knowledge of metallurgical, mechanical, chemical, electrical, mining, civil and ceramic engineers, as upon the plant workers themselves.

To assure employees opportunity for maximum personal development and provide a sound foundation for advancement in the organization are fundamental objectives of U. S. Steel. Employees participating in educational activities of U. S. Steel comprise a group exceeded in size only by the student bodies of a few of the nation's largest universities. In these educational programs, particular attention is given to the development of college graduates and other technically trained men.

For men who can qualify, a career with United States Steel offers a promising future.

AMERICAN BRIDGE COMPANY · AMERICAN STEEL & WIRE COMPANY · CARNEGIE-ILLINOIS STEEL CORPORATION · COLUMBIA STEEL COMPANY
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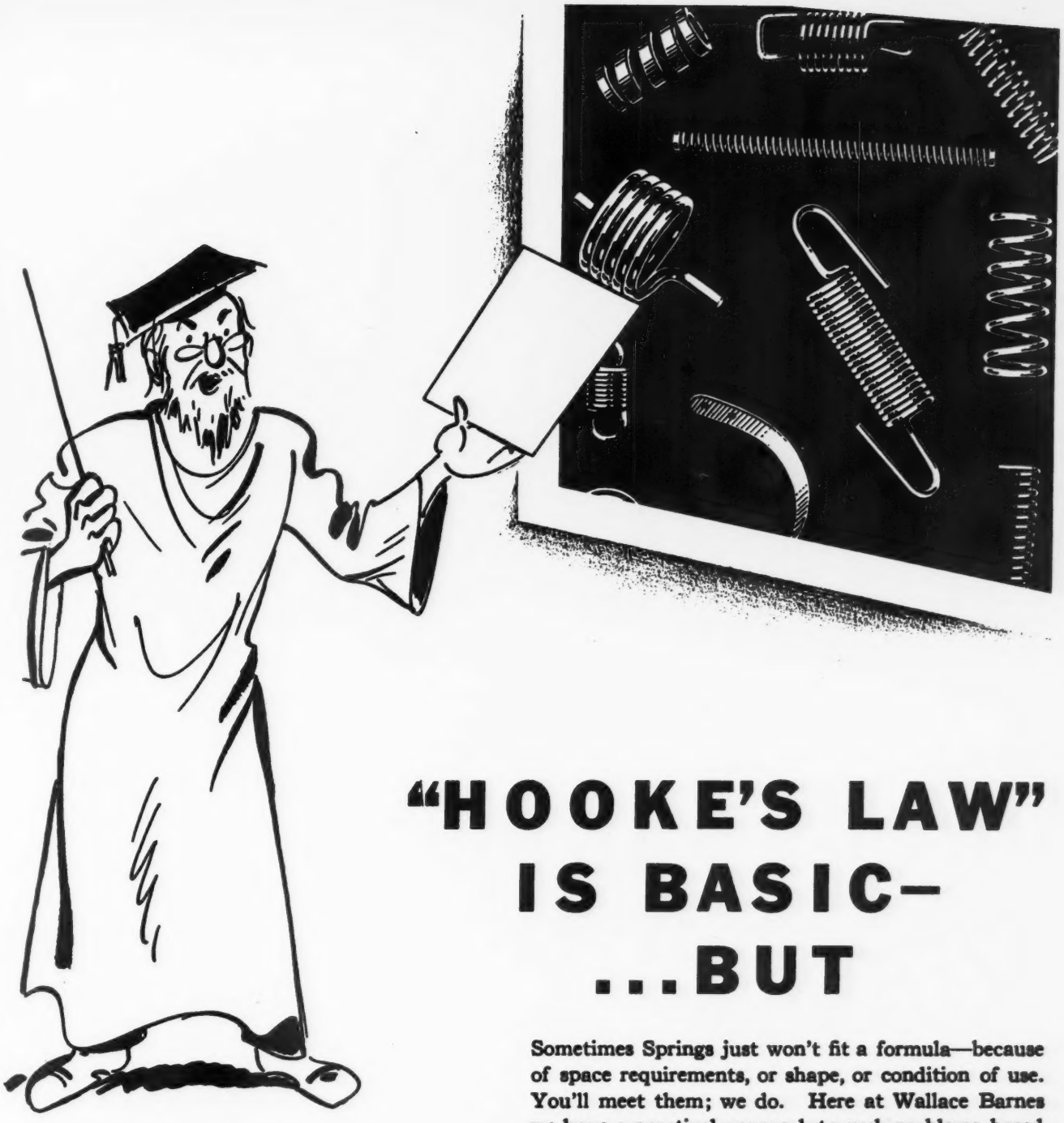
Quantitative Biology

The duration of each of the above undergraduate Courses is four academic years and leads to the Bachelor's degree, with the following exceptions: (1) Architecture and Marine Transportation, which are five-year courses leading to the Bachelor's degree; (2) Food Technology (Five Year Course), Physical Biology, and the Cooperative Courses in Electrical Engineering and in Mechanical Engineering, which extend over a period of five years and lead to the Bachelor's degree and the Master's degree.

Graduate study may be pursued in Textile Technology, Ceramics, Sanitary Engineering, and in most of the above professional Courses. The Master's and Doctor's degrees are offered in most of these fields.

For information about admission, communicate with the Director of Admissions.

The Catalogue for the academic year will be sent free on request.



"HOOKE'S LAW" IS BASIC— ...BUT

Sometimes Springs just won't fit a formula—because of space requirements, or shape, or condition of use. You'll meet them; we do. Here at Wallace Barnes we have a practical approach to such problems, based on experienced and specialized skill that should be helpful. Let us show you sometime how this engineering and production service can relieve you of many spring design problems in your chosen field.

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. . . a great name in research with a big future in CHEMISTRY

UNIQUE PLANT PRODUCES G-E SILICONES FOR INDUSTRY

On the outskirts of the little town of Waterford, N. Y. is one of the most unusual plants in the world.

New Waterford plant works night and day to produce silicones.

Where other new industrial structures may be impressive because of their physical size or tremendous productive capacity, the Waterford Works of General Electric is of interest because of the

Silicone oils are excellent mold release agents.

rare nature of the materials being produced there, and because of the new chemical processes involved in their manufacture.

Silicones from Sand

The primary raw material from which silicones are derived is sand. This basic ingredient is modified at Waterford through a complex series of pipes, tanks, stills, and reactors which are operated in a nearly automatic production system.

The most amazing property of silicones is that, like quartz, they are relatively unaffected by heat, cold, water, chemicals, and weather. But instead of being rigid, like quartz, silicones are flexible—they may take any form from liquid to solid! This flexibility permits them to be used in many

Silicone centers add new zip to U. S. Royal golf balls.

places where rigid materials with similar properties could not serve.

The finished silicone products are already being widely applied in industry, and new uses are constantly being found for them. Silicone rubber is being used for heat-resistant gaskets for aircraft and diesel engines, oven doors, and laboratory equipment. Silicone oils are excellent mold release agents for rubber and tire molders. Silicone resins promise to make possible paints and finishes of exceptional durability. Another product of G-E silicone research is called DRI-FILM*—water repellents that can be used on a variety of materials.

Tank farm stores liquid raw materials which automatic process converts to silicones.

Put Waterford on Map

You'll be hearing a lot about G-E silicones. They're really going to put that little town of Waterford on the map.

Of course, silicones are only one of the products produced by the various divisions of the General Electric Chemical Department. It also manufactures Glyptal* alkyd resins, insulating materials, permanent magnets, plastics molding compounds, and is responsible for the plastics molding operations that have made G. E. one of the world's largest plastics manufacturers. For more information, write to the Chemical Department, General Electric Company, Pittsfield, Massachusetts.

*REG. U. S. PAT. OFF.

A message to students of chemistry and chemical engineering from

J. L. McMURPHY

Manager, Chemicals Division, G-E Chemical Department

"The new world of organo-silicon chemistry is a fascinating one—and one which promises an interesting future for a young man who wants to make chemistry his career. We at General Electric are expanding our silicone research and production to meet industry's growing need for silicones."

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